DOCUMENT RESUME

ED 308 099 SO 019 921

AUTHOR	Roy, Rustum, Ed.
TITLE	Technological Literacy. Proceedings of the First National Conference (Baltimore, Maryland, February 14-16, 1986).
INSTITUTION	Pennsylvania State Univ., University Park. Materials Research Lab.
PUB DATE	86
NOTE	216p.
PUB TYPE	Collected Works - Conference Proceedings (021) -- Reports - Research/Technical (143)
JOURNAL CIT	Bulletin of Science, Technology, and Society; v6 n2-3 1986
EDRS PRICE	MF01/PC09 Plus Postage.
DESCRIPTORS	Blacks; Community Colleges; Educational Technology; Elementary Secondary Education; Ethnic Groups; Interactive Video; *Liberal Arts; *Minority Groups; Postsecondary Education; *Science and Society; *Science Education; Scientific and Technical Information; Technical Education; *Technological Advancement; *Technological Literacy; Videodisks
IDENTIFIERS	Video Technology

ABSTRACT

These papers, divided into six sections, provide an accurate indication of thinking about technological literacy (TL) in the U.S. "Main Problems and Issues" contains four papers which discuss the needs, challenges, and benefits of developing TL. "Technological Literacy: Concepts and Measures" includes six papers which discuss multi-disciplinary aspects, problems of measuring TL, and institutional implications of developing TL. "Higher Education" has 11 papers which look at the role of TL at various institutions of higher education, from universities to community colleges, and its implications for the liberal arts and sciences. "Kindergarten through Grade 12," contains eight papers which concern themselves with the methods, materials, and conceptual structures of programs to develop TL at those levels. "Technological Literacy and the Minority Learners" includes three papers which discuss the special role of the development of TL among minority and ethnic students. "Innovations in Educational Technology" presents four papers on the use of new technologies in the educational process, especially video and video discs. A discussion of the relationship between humanists and technologists, and a final essay on TL conclude this collection. (PPB)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED308099

SO 019921

BULLETIN OF SCIENCE, TECHNOLOGY & SOCIETY

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☐ This document has been reproduced as received from the person or organization originating it

☐ Minor changes have been made to improve reproduction quality

- Points of view or opinions stated in this document do not necessarily represent official OERI position or policy

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
Rustum Roy

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

2

BULLETIN OF SCIENCE, TECHNOLOGY & SOCIETY

The Materials Research Laboratory
The Pennsylvania State University
University Park, PA 16802 USA

Editor-in-Chief:
RUSTUM ROY

Managing Editor:
KATHLEEN S. MOURANT

Co-Editors:

Prof. JACQUES ELLUL
29 Avenue A. Danglade
33600 Pessac, France

Prof. S.L. GOLDMAN
Mellon Prof. in the Humanities
Lehigh University
Bethlehem, PA 18015 USA

Dr. W.F. WILLIAMS
Combined Studies
Faculty of Science
University of Leeds
Leeds LS2 9JT, UK

Book Editor:

Prof. JOSEPH HABERER
Program in Science, Technology and Public Policy
Department of Political Science
Purdue University
West Lafayette, IN 47907 USA

Special Issues Editor:

Prof. LEONARD J. WAKS
Science, Technology and Society Program
The Pennsylvania State University
University Park, PA 16802 USA

Associate Editors:

Mrs. VALENTINA BORREMANS
President, Tecno-Politica
Apdo. postal 479
Cuernavaca, Mor., Mexico

Prof. KENNETH E. BOULDING
Institute of Behavioral Science
University of Colorado
Boulder, CO 80309 USA

Dr. GEORGE BUGLIARELLO
President, Polytech University
333 Jay Street
Brooklyn, NY 11201 USA

Prof. LYNTON K. CALDWELL
Director, Advanced Studies in Science, Technology and Public Policy
Indiana University
1800 N. Fee Lane
Bloomington, IN 47405 USA

Prof. BARRY COMMONER
Director, Center for the Biology of Natural Systems
Queens College
Flushing, NY 11367 USA

Dr. EDWARD E. DAVID, JR
President, Exxon Research and Engineering Company
RT 22 East Clinton Township
Annandale, NJ 08801 USA

Prof. FRANKLIN A. LONG
Cornell University
608 Clark Hall
Ithaca, NY 14853 USA

Prof. Dr. KLAUS M. MEYER-ABICH
Senator
Hamberger Straße 37
2000 Hamberg 74
F.R. Germany

Dr. HELGA NOWOTNY
European Center
Social Welfare Training and Research
Berggasse 17
1090 Vienna, Austria

Prof. ROGER SHINN
Union Theological Seminary
3041 Broadway
New York, NY 10027 USA

Dr. KLAUS-HEINRICH STANDKE
United Nations Development Programme
One United Nations Plaza
Room DC-2092
New York, NY 10017 USA

Prof. JOHN G. TRUXAL
Department of Technology and Society
State University of New York
Stony Brook, NY 11794 USA

Prof. ERIC-JAN TUININGA
Faculteit der Wiskunde en Natuurwetenschappen
De Boelelaan 1083
1081 HV Amsterdam
The Netherlands

Prof. ERNST U. von WEIZSÄCKER
Director, Institute for European Environmental Policy
Aloys Schulte Str. 6
53 Bonn, F.R. Germany

Prof. LECH W. ZACHER
Institute of Management
Polish Academy of Sciences
Palace of Culture, Pushkin Hall
00-901 Warsaw, Poland

Prof. JOHN ZIMAN
Science Policy Support Group
114 Cromwell Road
London SW7 4ES, U.K.

Editorial Office: *Bulletin of Science, Technology & Society*, Materials Research Laboratory, University Park, PA 16802 USA. Telephone (814) 865-1137.

Publishing, Subscription, and Advertising Office: STS Press, Materials Research Laboratory, University Park, PA 16802 USA. Telephone (814) 865-1137.

Published bimonthly. Annual subscription rate (1985) $85.00 for libraries and other multiple-reader institutions; two-year rate (1985-86) $161.50. Professional rate (1985) $30.00. Special Educator's rate (1985) $25.00. Prices include postage. Air mail subscriptions extra.

Free copying of educational material. Subscribers may reproduce without charge any of the articles, educational modules, curricula and course outlines that are published in this journal, provided they are not resold.

Copyright © 1985 The STS Press

Reproduction rights are granted to subscribers under terms described above. All other reproduction is prohibited without permission of the copyright owner.

BULLETIN OF
SCIENCE, TECHNOLOGY & SOCIETY

Volume 6, Numbers 2 and 3 1986

INTRODUCTION

RUSTUM ROY
Technological Literacy--Clarifying the Concept and its Relation to STS 131

MAIN PROBLEMS AND ISSUES

ERICH BLOCH
Scientific and Technological Literacy: The Need and the Challenge 138
CECILY CANNAN SELBY
Technological Literacy: A National Imperative and Benefit 146
RICHARD D. LAMM
Columbus and Copernicus 152
GEORGE BUGLIARELLO
Colleges and Universities versus Schools: Shall the Twins Meet? 159

TECHNOLOGICAL LITERACY: CONCEPTS AND MEASURES

WILLIAM F. WILLIAMS
The Rationality of Technological Literacy: Introduction to Section on Concepts and Measures 163
STEPHEN JAY KLINE
The Logical Necessity of Multi-Disciplinarity: A Consistent View of the World 164
LEE SMALLEY
Technology Education: From Where to What? 188
JON D. MILLER
Technological Literacy: Some Concepts and Measures 195
PAUL W. DeVORE
Measuring Technological Literacy: Problems and Issues 202
DAVID LAYTON
Empowerment of People: The Educational Challenge of Science for Specific Social Purposes (SSSP) 210

HIGHER EDUCATION

LANGDON WINNER
On the Foundations of Science and Technology Studies 219
JOSEPH HABERER
Technological Literacy and the University: Concepts, Priorities, and Political Realities 222
DONALD deB. BEAVER
Technological Literacy, Old and New 229
CARL MITCHAM
The Liberal Arts in a High Tech Society 235
JOHN P. BROCKWAY
Technology & The Liberal Arts 240
JUDITH ADAMS, PAUL DURBIN and RACHELLE HOLLANDER
Research in STS Studies 246
STEPHEN H. CUTCLIFFE
STS at Lehigh University 255
CORRINNE CALDWELL
Science, Technology and Society in Community Colleges: An Introduction 257
JAMES C. WILLIAMS
Science, Technology and Society in the Community College 259

M. GARRETT BAUMAN and ROBERT H. HERZOG
STS in the Community College: The Human Ecology Program at Monroe Community College 261
NEAL A. NORRIS
Learning at the Interface: Doing Community College STS Education as if Tomorrow Really Mattered 268

KINDERGARTEN THROUGH GRADE 12

ROBERT A. YAGER
To Start an STS Course in K-12 Settings 276
IRMA S. JARCHO
Science, Technology, and Society Education: Methods and Materials 282
MINARUTH GALEY
Using Television to Bring Science, Technology and Society into Secondary Schools 287
DAVID L. McCRORY
A Conceptual Structure and Study Guides for Teaching About Technology 291
DARREL W. FYFFE
A Middle School S-STS Teacher Education Program 294
HERBERT D. THIER
The Value of a Science/Technology/Society Emphasis in the Elementary School 298
JAMES R. GEISE
The Social Studies Side of the S/T/S Connection 301
PETER A. RUBBA
Issue Investigation and Action Skills: Necessary Components of Precollege STS Education 304

TECHNOLOGY LITERACY AND THE MINORITY LEARNERS

DANA R. FLINT
Science, Technology, and Society and the Empowerment of Minority Students 308
ARGELIA VELEZ-RODRIGUEZ
Technology Literacy and Ethic Minority Students 311
JAMES B. STEWART
STS and Black Studies: Partnership for Progress in the 21st Century 315

INNOVATIONS IN EDUCATIONAL TECHNOLOGY

FRANK B. WITHROW
Education Technology: Innovations 319
KATHY WILSON
The "Voyage of the Mimi" Prototype Videodisc 321
DENIS NEWMAN
Classroom Research on Interactive Video 323
ANN ERDMAN
Notes on "World of Work" Videodisc 326

MISCELLANEOUS

SOTIRIS C. KITSOPOULOS
Humanists, Technologists and the Gap Within 328

AFTERWORD

LEONARD J. WAKS
Reflections on Technological Literacy 331

Introduction to Technological Literacy Issue

These papers, with just a few exceptions, were first presented in February, 1986, at the First National Technological Literacy Conference. They do not reflect a single point of view, but rather reflect various, sometimes even contradictory, approaches now being made to the issue of technological literacy.

W.F. Williams and Rustum Roy helped with the organization of the issue, and the former also provided editorial assistance at every stage of the process, from initial selection of papers to copy editing.

As a group, these papers provide an accurate indication of 1986 "state-of-the-art" thinking about technological literacy in America. They are by no means the last word on the subject. They are presented as a useful starting point for the deep thinking which is now demanded. As W.F. Williams says in his paper, there is so much about this issue which we need to learn.

Leonard J. Waks
Special Issues Editor

Bull. Sci. Tech. Soc., Vol. 6, pp. 131-137, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

TECHNOLOGICAL LITERACY--CLARIFYING THE CONCEPT AND ITS RELATION TO STS

Rustum Roy

Literacy, Unnecessary for Technological Competence

In 1986 Ivan Illich, who a decade earlier had had the temerity to question the unalloyed beneficience of the techno-medical machine,[1] saw fit to question an even more sacred cow of "developed" societies.[2] He questioned whether the almost universally sought goal of "literacy" was a desirable goal. Illich was, of course, no stranger to counter-intuitive seminal thinking about education; "Deschooling society" was published in 1971. But this argument certainly gets attention by again questioning what virtually everyone takes as a "good." It is a good place to start a paper on "Technological Literacy," because that term certainly conveys a general sense of a desirable societal goal. Therefore, in preparing this paper I was forced to deal with Illich's thesis, that the written word (and letters) and the alphabetization of culture have traded a narrowing (impoverishment) of the band-width of signal receivers for the ability to "broadcast" even this partial message to larger and larger audiences. This thesis is profoundly relevant to all of us who are concerned with "increasing the technological literacy" of the general public. Is this goal itself a universal good? Or is the term imprecise and less than optimum, because one can conceive of the case when a gain in "literacy" may not advance the cause of certain competence in technological matters.

Table 1.
Different Modalities of Inter-Person Communication
Used in Different Technologies.

	Oral Speech	Telephone	Written Word	Computer*	Audio Tape	Video Tape
Sounds (words)	✓	✓	✓ Nearly Equivalent	✓ Small Subset	✓	✓
Intonations	✓	✓	X	X	✓	✓
Facial Expression	✓	X	X	X	X	✓
Whole-body Gestures	✓	X	X	X	X	✓
Actions	✓	X	X	X	X	✓
Interaction	✓	✓	X	X (?)	X	X

*Restricted to its proper "computing" function, using the language of mathematics.

"Literacy" is the technology of using letters and words. It is one of several such used to aid or substitute for direct oral speech as a means of communication. I have summarized in the table above the differences between what happens between two humans when communication occurs using different "technologies." It is clear that oral speech between two persons employs a much richer mix of "signals" than say written words. The telephone is better than writing and the VCR much better than both. The major lack between the latter two when compared to direct speech is the absence of immediate interaction and feedback. The relevance of this table will become evident when one discusses how technology is best passed on from one human to another. Is literacy--the ability to read and write--necessary to technological functioning? Or could it even be a handicap? That is the relevance of Illich's thesis to our topic.

What Then is Technological Literacy (T.L.)?

I list below five different aspects of the term T.L.

1. T.L. is a Complex Multidimensional Reality

Viktor Frankl uses the simple example of the visual perception of a solid object to illustrate how different the same object looks from different viewpoints. T.L. looks very different when looked at by different groups.

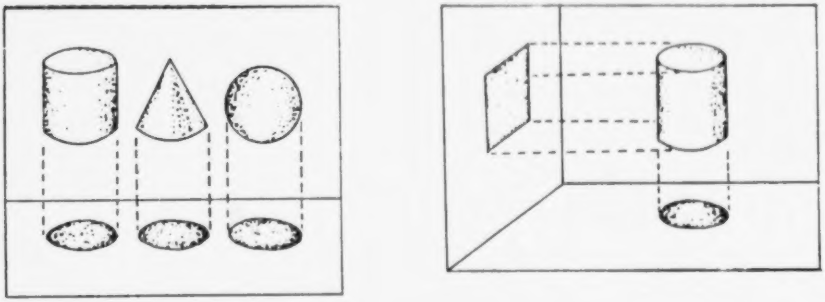


Figure 1. The reality perceived is drastically affected by the direction from which it is viewed. Viewing from more than one direction may give an unexpected addition (in this case the 3-dimensional nature) to our model of reality. (After V. Frankl.)

The industrial manager looking for more technologically literate employees, the College dean concerned about her B.A. degree holders, and the anti-nuclear activist probably have rather different views of T.L. Yet all these apparently contradictory views may describe the same total reality.

2. T.L. is a Slogan (See paper by Waks[3] for a detailed treatment)

Slogans are extremely valuable as general rallying points for the masses. "Technological literacy" as a slogan conveys accurately--though not precisely--what we would like it to convey. One should not expect too much of such terms. We all agree that "technological illiteracy" is a "problem." Fritz Schumacher of "Small is Beautiful" fame in his Guide for the Perplexed[4] distinguishes between convergent and divergent problems. The former we can solve, bring to a sensible conclusion, wrap up. The latter "divergent" problems we can address, discuss, work away at, knowing that in essence they cannot be "solved." "Technological Literacy" becomes the slogan for gathering a heterogeneous group of concerned citizens to address the problem. The lack of precision in the term may be made into a virtue, so that a variety of individuals with differing approaches may still cooperate in that part where their interests do overlap.

3. T.L. is a Paradox

This observation forms a key component of my thesis. Humans developed many technologies to quite sophisticated levels millenia before they were literate (i.e. able to use an alphabet to make words which they could pronounce and/or understand). Could the term "technological literacy" therefore be an oxymoron.[2] Clearly technological competence, i.e. carrying out certain technological procedures does not require the ability to read or write. In the developed world many of us experience this in dealing with very competent automobile mechanics who are almost technological experts in car maintenance but may be illiterate. In the developing world this is commonplace. Thus M.S. Swaminathan[5] discussing the transfer of agricultural biotechnologies to the third world also reported that in many developing countries quite complex biotechnologies of plant breeding and pest control have been passed on from generation to generation by totally illiterate villagers. Indeed to train personnel to perform the same tasks by the standard procedures of literacy, training in science, and learning the techniques would be a formidable, indeed prohibitively difficult and complex a task for a local government. Literacy is clearly neither necessary nor sufficient for technological competence. We will therefore be forced to attempt some definition of the terms we use, and I attempt below to add some new terms which are helpful in the development of this topic.

4. Technological Literacy is Not Analogous to "Scientific" Literacy

Following Illich's approach, sketchily referred to above, the development of the alphabet both constrained human communication and simultaneously made it much easier to communicate with large numbers at lower levels of "intensity." The scientific alphabet--of mathematics, symbols, and equations--continued this trend and generated an enormously powerful communication tool, albeit to a correspondingly narrower and narrower group of individuals. Just so, since science requires the literate, letters, scientific literacy is a meaningful and non-paradoxical term.

5. T.L. is Better Described as a Continuum of C^3T: Comfort with, Competence in, and Control of Technology

In order to discuss this in some depth let us attempt some definitions of the terms as we are using them here.

Technology is the means by which humans utilize natural and human resources to attain a goal.

Literacy is the ability to communicate through written letters and words.

Uncomfortable with technology is the state where due to ignorance, one is both wary and afraid even of the means one must use on a daily basis to attain one's goals.

Comfortable with technology is the state in which a human being is at home with, the technological means that she or he uses, but unable to assess their impacts on persons or society.

Competence in technology is attained when one has acquired the skill to operate competently the means needed for attaining one's goals.

Control of technology requires, in addition to operation, a level of understanding of the process to shape and adapt it as necessary to achieve even new goals based on an assessment of its potential for good and ill.

Perhaps the use of an analogy will help illuminate these terms (see Fig. 2). A tourist in a foreign land needs the technology of language. The person who has no familiarity at all with the language feels at a major disadvantage, has to use sign language to order food

a. ILLITERATE in native tongue.		
One can manage, millions do!! How? Led around by others. Sign language. Use pictures, maps. Trial and error.		Uncomfortable No competence Little control
b. BERLITZ Course		
You do it and put word to it. Walk around city Eat in restaurants Visit castles	Minimal interaction	Some comfort Little competence No control
c. FLUENT in local language		
Participate in life of city WORK, INTERACT		Comfort Competence Control

Figure 2. Levels of C^3T. Tourist Metaphor: How to get around city?

or find the bathroom, and can develop a real sense of isolation. The vast majority of citizens in the developed world surrounded by a myriad technologies are in this state with respect to most of them--discomfort caused by gross ignorance of a functioning system in which they have no choice but to participate as cogs. Such persons are not only "illiterate" in the native tongue, but cannot speak or understand it either.

A second group of tourists, in preparation for their trip, will have taken a crash course in the language, acquired a phrase book, or taken the Berlitz course in it. While they are still not literate in the new language they are much more comfortable in their environment. They can "manage," without discomfort, but since they cannot read signs or a newspaper still can have no sense of competence.

A third group has studied the language (or grew up with it) so that they can be rather fluent in it. It is only they who can experience C^3T. There is, of course, a fourth group which is a subset of the third. These are the writers or poets of the language. They are sufficiently in control to invent new expressions, alter meanings--shape the language itself.

Optimal Technological Fluency

If we define T.L. as we have done above then it becomes clear that it is a "situational" term. How much competence and control, C^3T, one "needs" is certainly a function of one's environment and responsibilities. As Figure 3 attempts to convey, there is no such thing as general technological fluency. The "literacy" level is therefore very different depending on whether the individual is a Senator chairing her sessions of the Armed Services Committee, or a baker in a small town. What "increasing fluency in technology" requires is a widening of the concerns in C^3T with respect to both space and time. A person highly technologically competent in computer software or auto repair would not necessarily,by any means, be technologically fluent at the level of a town councilperson or company vice president. This phenomenon explains why scientists are so often "on tap" instead of "on top"--because of the narrowness of their competence in the two dimensions of Fig. 3. Technological literacy then may be described as the level of C^3T commensurate with one's role in society.

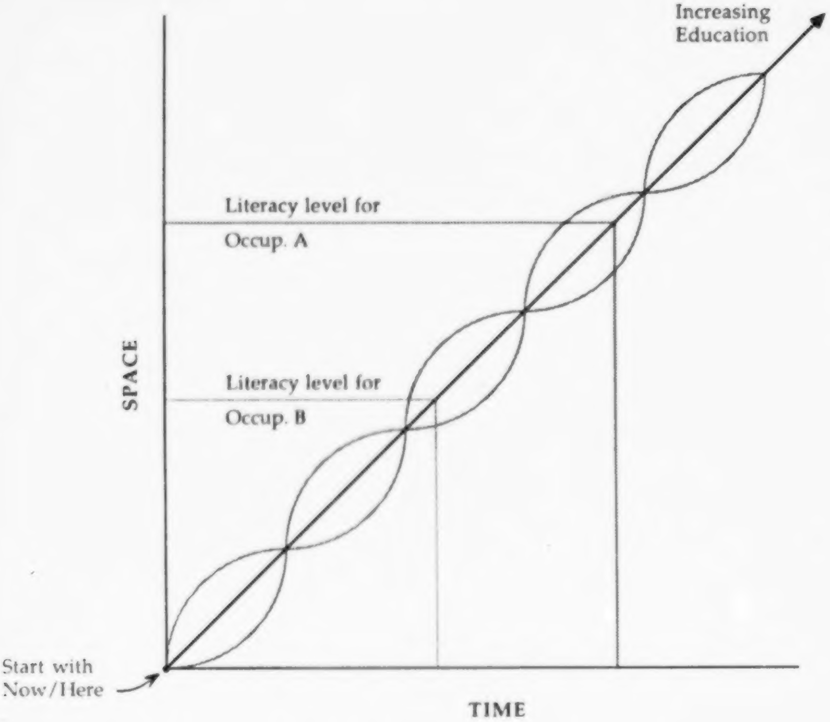


Figure 3. There is no such thing as General Technological Literacy. Only the most educated, most powerful in society need to be generally technologically fluent. The less educated can manage with more specialized T.L., i.e. whatever is needed to given the C^3T for their own life.

How Does STS Help Achieve C^3T

1. By Relating Everything to Human Beings and Human Society

We have noted above that C^3T is not achieved, as is scientific literacy, by acquisition of abstract knowledge or skills. The fundamental relation between T.L. on the one hand and STS on the other is the personalization of that connection to technology, STS uses the human reference point wherever possible.

This recognition of the importance of the human scale is not new to science. P.W. Bridgman, Nobel Laureate in Physics, wrote three decades ago

> *"Finally, I come to what it seems to me may well be from the long range point of view the most revolutionary of the insights to be derived from our recent experiences in physics, more revolutionary than the insights afforded by the discoveries of Galileo and Newton, or of Darwin. This is the insight that it is impossible to transcend the human reference point . . . . Furthermore, I believe the experts would at present agree that whatever new*

> *way we devise to think about the microscopic universe, the meaning of our new concepts will have to be found back at the level of the large-scale events of daily life, because this is the scale on which we live our lives, and it is we who are formulating the new concepts."*

And James B. Conant, chemist, former President of Harvard, wrote along the same lines:

> *"It seems to me more likely that the average citizen will come to think of science in totally different terms from those employed in explaining science to lay audiences fifty years ago. If I am right, in order to assimilate science into the culture of our twentieth-century highly industrialized society, we must regard scientific theories as guides to human action and thus an extension of common sense."*

2. By Relating to Daily Life

For the typical citizen therefore C^3T might be related to the individual in the following ways at each of its levels

C^1 should provide coping skills for daily living (dealing with one's car, toaster, fuses, boiling water efficiently! etc.)

C^2 should provide major contribution to livelihood skills in a technological culture.

C^3 should provide essential preparation to exercise control over individual's and collective future via citizenship role.

STS education for "technological literacy" therefore needs some radically new approaches. The following suggest themselves immediately.

1. Perform time and contact studies of individuals' contacts with technology in daily living. STS-Education must assure their hands-on COMFORT with these daily tasks.
2. Cater to learner-demanded deepening of interest and skill for vocation.
3. Provide practice in exercising "control" in personal, then local, then regional, etc., situations involving technology and show links to values at all levels.

T.L.: Does It Matter? Can You Tell?

For all of us who advocate a new integration of technological realities into the myriad societal processes now in place, the key question becomes: Would it make any difference to the "technological literacy" if the citizens had a more thorough STS-education? The example below shows what one would hope to achieve by "technological literacy" as defined as the appropriate level of C^3T for a voting citizen of the western world.

Differing Reactions to Chernobyl

"Technologically Illiterate"	"Technologically Literate"
• Self-concept reinforced (I can't understand all this!)	• Critical evaluation of data (radiation level compared to background, chest x-ray, etc.)

• Fear reaction persists, because it must remain unknowable	• Reaction based on comparison and quantification of threat level
• Herd response--"masses" are formed by their shared T.I. and can be manipulated or led astray easily.	• Individualized response based on data + values

It can be said with considerable confidence that the vast majority of STS programs would move the students involved up the ladder shown in Fig. 3, of a greater knowledge and concern for events further removed from ourselves in both time and space. Insofar as that is true, this rising tide would lift the technology literacy level of large numbers of citizens.

Technological Literacy and the STS Community

The papers in this volume are testimony to the fact that a large number of secondary school teachers, University faculty, and public servants and public figures can make common cause around the slogan of "Technological Literacy." The task of improving the technological comfort, competence and control of the U.S. population is of such crucial importance that nothing less than a concerted effort by all the educators in society can succeed.

References

1. Ivan Illich, Medical Nemesis, 1977, Penguin Books, NY.
2. Ivan Illich and Barry Sanders, ABC, the Alphabetization of Culture, North Point Press, San Francisco, CA, 1986.
3. Leonard J. Waks, "Reflections on Technological Literacy," this volume.
4. E.F. Schumacher, A Guide for the Perplexed, 1977, Harper & Row, NY.
5. M.S. Swaminathan, "Genetic Heterogeneity and Ecological Sustainability of Food Production Systems," AAAS Meeting, Philadelphia, PA. May, 1986. Abstracts, p. 50.

RUSTUM ROY is Evan Pugh Professor of the Solid State and Director of the STS Program at The Pennsylvania State University, 128 Willard Building, University Park, PA 16802. He serves as Chair for the Technology Literacy Conferences, is the Director of the Science through Science, Technology and Society Project, and Editor-in-Chief of The Bulletin of Science, Technology & Society.

Bull. Sci. Tech. Soc., Vol. 6, pp. 138-145, 1986. Printed in the USA.
0270-4676/86 STS Press.

SCIENTIFIC AND TECHNOLOGICAL LITERACY: THE NEED AND THE CHALLENGE

Erich Bloch

I am very pleased to be invited to this conference and to address you today on the subject of technological literacy. I am particularly interested in this issue and concerned about it. That is not only because I direct an agency with a special responsibility in science and engineering education. Literacy in the sciences and mathematics is the underpinning of our research enterprise--a key element of our continued national well-being. Or, to take the title of this session, it is a national imperative.

Science and technology play an increasingly vital role in our life. Our research and our ability to innovate are the basis of the quality of our lives and of our economic competitiveness.

People generally recognize this. A recent survey of public attitudes shows that Americans are interested in science and technology. Their respect for scientists is exceeded only by their respect for the medical profession. And they are confident that science and technology will solve many important problems.

The signs of public interest are easily observable. Science and technology magazines are popular. So are personal computers, for both practical and entertainment purposes.

These trends might tempt us to conclude that the general population of the United States enjoys a high level of scientific literacy.

But that would be a serious mistake. Knowing how to use a computer is not the same as knowing mathematics, nor does reading Omni, or a science fiction novel, teach physics or astronomy.

The people surveyed by NSF seem to understand this. Three quarters of those who are interested in science and technology also admit that they don't know very much about either one.

The facts bear out this observation. In comparative international tests our students are not only outscored by those of other nations; they often place last. U.S. students rank in the lowest quartile in knowledge of geometry, along with countries such as Chile, Thailand, and the Ivory Coast. Our students rate well below those of some of our most important competitors, especially Japan and the Soviet Union.

We know that too few students complete high school with enough science and mathematics to allow them to do college-level work in the sciences. And we also know that we are not training enough scientists and engineers.

Too many of our young people are insufficiently prepared to face the increasingly complex and technological world we live in. In other words, we have a serious problem of technological literacy.

On the other hand, our research scientists and engineers are the best in the world. Is this a contradiction? I don't think so. What it suggests is a gap between the talented people that science attracts and the rest. This is a danger: tacit acceptance of a policy of elitism through benign neglect of our general population will be self-defeating and dangerous in the long run.

Scientific and Technological Literacy

What does it mean? It certainly does not mean that all citizens must be professionals. But it does mean that all who finish high school should be reasonably comfortable with popular presentations of scientific and technical subjects.

> Anyone who finishes high school should be able to read a newspaper or magazine article on technology-related issues of the day, such as medical research, environment, automation, or nuclear power.
>
> More important: High school graduates should be able to react to science policy issues that touch their lives not just on the basis of emotion, but on the basis of some understanding. They should be able to ask:
>
> - What are the facts?
> - What are the risks?
> - Do we know enough?
> - Who can be trusted to make the right decision and what is the decision process?
> - What are the consequences of different views?
>
> And any graduate should be able to make informed choices about educational and career directions.

In short, scientific and technological literacy should provide an informed basis for public decision making. And pursuit of this objective is no longer a luxury. Scientific literacy is a national necessity.

Scope of Speech

I want to discuss with you today the implications of this problem and what we need to do to confront it. I will mention what the national science foundation is doing, and our recent efforts to examine and redefine our role in science education.

But to understand the full significance of the subject, we need to place it in a domestic and international context. So I will begin by commenting on the economic challenge facing this nation and its relationship to research and education.

Economic Challenge

In the last decade the economic environment of our nation has changed in important ways. There has been a shift to a global economy. Where we once were dominant and self-sufficient, we now confront sharp international competition in many areas. In science and technology, where we were once unquestioned leaders, we now face new challenges every day.

- Since 1970 the dollar volume of world trade has grown sevenfold.
- New competitors challenge us in both traditional areas and in both old and new technology. Japan and the Pacific rim nations--Taiwan, Korea, Singapore, Malaysia, and Hong Kong--are more important trading partners than Europe. And Brazil, India, and Indonesia clearly intend to become major economic powers.
- The market for nearly all significant manufacturing industries has become worldwide. In a total reversal of the pattern of 30 years ago, 70% of the goods we produce must compete against merchandise from abroad on international markets.

These developments have had a fundamental and irreversible effect on our economy. We are all aware of the challenges on our economy. We are all aware of the challenges to our automobile, electronics, and, of late, our semiconductor industries.

In 1985 trade imports of automobiles and telecommunications equipment, two areas we once dominated, cost us $8.1 billion and were a major part of our record trace deficit.

In addition to competition in trade goods alone, we are experiencing competition in research itself, which is the major way we have to maintain industrial competitiveness. Computers and biotechnology are important examples of research areas in which we face important challenges.

- We have heard a good deal about the Japanese 5th generation computer program. But we also face more immediate competition. The Japanese vector computers are not yet comparable to the best U.S. machines, but Japan has made a major national commitment to research in this area.
- We may face a similar problem in biotechnology, where there is a potential for almost unlimited practical benefits. In time, we may be able to cure mental diseases such as depression and schizophrenia, immunological disorders, Alzheimer's disease, and many others. We may also revolutionize agricultural production and even key manufacturing processes. But we will not gain the benefits of this if we let the research advantage pass to our competitors.

Other nations have gained a competitive edge on us for a variety of reasons, including cheap labor and lower interest rates. They protect their industries from foreign competition and subsidize their exports.

Still, the United States enjoys two clear advantages in international competition: The first is the innovativeness of our scientists/engineers, resulting in a vigorous flow of new ideas and discoveries. Second is our natural resouces and the diversity and flexibility of our workforce.

To sustain our advantage we must maintain the flow of ideas and the human resource pool which makes their development and adaptation possible.

Scientific and Technological Literacy: Science Education

Even more than today, the scientific and technological literacy of our nation in years to come will be the cornerstone of our competence and productivity.

The employment of scientists and engineers increased three times faster than total U.S. employment in the last decade. Scientific and technical employment has grown three times as fast as the real GNP and twice as fast as total professional employment. This means that our nation's economy is based increasingly on scientific and technical activities. They are the key to our well-being.

The domestic and international economic challenge we face is one compelling reason for pursuing policies which support science education at all levels of the educational process.

There are others. In addition to the relatively small number of individuals who go on to graduate school to become scientists, research engineers, and doctors, there are many more needed to become technicians, practicing engineers, and effective employees in numerous service industries.

And we need scientifically literate lawyers and teachers, parents and politicians, government and factory workers, and writers.

Our modern industrial society confronts us with tough issues that require some understanding of the science involved. Toxic wastes, acid rain, nuclear power, and space-based defense systems are current issues. They will be joined by others. We can be sure that the search for new knowledge and innovation will pose new policy issues that the public will have to judge--and, more important, to understand.

We may also hope that the search for knowledge will be valued for itself, as a way of enriching our lives and allowing us to understand the beauty and excitement of the universe we live in. We need a public that understands this value for their own lives, and for their nation.

The Role of Education

People acquire their interest in science in many ways:

- Children may be stimulated by their home environment.
- Television programs and museums may awaken interest.
- A home computer may stimulate a broader interest in science and mathematics.

But the most important exposure occurs in schools, through courses, interactions with teachers, and special activities.

Studies have shown repeatedly that attitudes toward science and math are formed in the early grades, and competence in technical fields originates at this level as well.

We are fortunate that our young people are, in fact, fascinated by scientific discoveries and the use of new inventions and technologies. The same NSF study that demonstrates high levels of interest in science by the adult population also tells us that young people are particularly interested, regardless of grade level, or college attendance.

But we also have a problem. Interest is not the same as literacy or competence. And it would be a mistake to conclude that this widespread interest will result in the development of the human resource base necessary for our domestic well being and our international leadership.

We are short of advanced degree engineers to staff our universities and government and industry laboratories. At a time when industry needs more Ph.D.'s than before, our production of Ph.D. engineers has been declining since 1976 and only now shows signs of improvement.

It would be premature to celebrate this upturn in a worrisome trend. In the next decade, an expected wave of retirement of a large proportion of teaching faculty will strain further the already inadequate teaching force in colleges and universities.

Since 1981, foreign nationals have received over half of the U.S. doctoral degrees in engineering, an increase of more than 100 percent since 1959. It is true that we have benefitted from this influx of foreign talent. They make a vital contribution to our industries and academic institutions. But it would be unwise for us to become dependent on uncertain sources of supply that are subject to disruption by international politics.

There is another problem. Enrollment in science and engineering will decline along with the size of the college-age population unless we succeed in attracting a larger proportion of individuals to these disciplines. The shortage will be compounded by the changing composition of the work force. By 1998 an increasing percentage of college students will be minorities and women. In the past, these groups have been less likely than white males to select quantitative fields of study because their education did not attract them to math and science early enough!

All this underscores the importance of laying the foundation where it counts most: at the primary and secondary levels where basic science and math competence is first established.

Meeting the Challenge

We face a problem. How well prepared are we to deal with it?

We know that qualified, committed science and mathematics teachers can be found in schools throughout the nation at all levels. Christa McAuliff was an example. We also know that state and local governments across the country are making a significant commitment to education and are experimenting with new forms, such as magnet schools.

But there are too few trained science and math teachers who can provide the proper inspiration and support for their students in these disciplines. Not enough science and math courses are made available, or required during the early school years, and there are not enough trained teachers.

Clearly, recruitment of new teachers, special training, and retraining of existing teachers, is a fundamental requirement for providing quality education in the sciences, in a quantity sufficient to meet the need.

There is also a need for instructional equipment, access to laboratories and field trips, and updated and improved curricula.

Many reports have been issued in recent years on the problem of science education--by the National Science Board, the Carnegie Institution, the National Academy of Sciences, and the Department of Education, just to name a few. They have helped build a national consensus on the need to upgrade science education in the schools.

This consensus has been important in sharpening the focus of institutions like the National Science Foundation on the precollege level, and particularly on improving the competence of our teachers.

NSF Activities and Programs

Both this year and in fiscal 1987 the Foundation intends to spend more than $50 million on a variety of precollege science education programs. Their purpose is to:

- improve the preparation of new teachers;
- provide subject matter re-education for in-service teachers;
- revise instructional materials;
- explore advanced technologies that can assist teachers in teaching their subjects.

NSF's efforts focus on strategies and activities where its unique strengths and leadership can have the greatest impact.

- The projects we support are designed to leverage or stimulate a wide range of additional, complementary activities. By this means, we maximize the impact of our limited financial investment;

- The results of these projects must be widely shared and disseminated. We emphasize the development of models and ideas that can be applied by local systems throughout the nation.

- They must meet high standards for scientific content; active participation by practicing scientists and engineers in these activities is fundamental.

In other words, we strongly encourage partnerships among all those with an interest, expertise and stake in precollege education. This includes state and local education agencies, private industry, colleges and universities, professional societies and museums and foundations.

By means of these partnerships we encourage cost-sharing arrangements and the sharing of ideas and experiences.

Examples of the Activities We Support

Teacher Training and Improvement

I mentioned earlier the critical importance of improving the competence of our teachers. Most elementary school teachers receive virtually no formal training in science or mathematics or in teaching these subjects. We have several activities that focus on this need.

- The Foundation supports the development of specialized materials and courses to improve teachers' knowledge of their subject areas.

- In addition to responding to unsolicited proposals, NSF is issuing formal solicitations to stimulate changes in the process of preparing teachers for their responsibilities.

- To improve the abilities of in-service teachers, we train master teachers to assist their colleagues by providing enrichment in subject content and teaching methodology.

- We recognize outstanding teachers through our Presidential Awards for Excellence in science and mathematics teaching. In 1985 we honored 104 secondary school teachers from the fifty states, District of Columbia, and Puerto Rico. The modest cash awards that accompany these nominations--$5,000 to the teacher's school to supplement its programs--are enhanced by donations from the private sector.

Materials and Methods

A variety of books, films, and hands-on instructional materials were developed in the 1960's and 1970's with substantial NSF support. We are issuing a call for proposals to update elementary school materials and to revise mathematics programs in the early grades.

Technologies

Modern information technologies such as computers, graphics systems, videodiscs, and tv transmission technologies are important teaching tools. NSF supported pioneering work in the development of LOGO, BASIC, and videodisc technology for education years ago. We are building on this tradition and supporting work on prototypes of new hardware, software, systems, and languages.

Informal Education and Public Understanding

Improving what goes on in the classroom is vital. But it is not enough. Particularly in the early years--kindergarten through the sixth grade--children receive little and sometimes no formal exposure to science.

Television can be a significant educational tool, as we all know. And we also know how much time children spend in front of it. Yet just ten years ago, there were no science programs for children on tv at all.

Here again, with respect to reaching out and supporting informal education in the sciences, NSF applied the same principles that govern its other programs:

- leverage resources
- stimulate involvement with others
- develop models
- build partnerships.

NSF generated several important television programs: Nova, 3-2-1-Contact, and the recent series on the brain. The current estimated audience for 3-2-1-Contact is 10 million children, and the program enjoys strong support from the private sector. In six months, there will be a comparable series for children on mathematics, again, sponsored by NSF.

The success of Nova, and of the public radio program, "All Things Considered" has also resulted in a broadening of public interest and support, and of private sector involvement. NSF's sponsorship of the radio program, for example, has been taken over by a private business firm--Hewlett Packard.

NSF also provides support to science museums and has been instrumental in the organization of the association of science museums.

NSF's newest venture to encourage public understanding of science is National Science Week. This coming May, from the 11th to the 17th, will mark the third year that the Foundation helps focus national attention on encouraging young people to become involved in science. This effort, completely supported by private donations, encourages local communities to organize science projects and demonstrations through libraries, schools, and science museums. University, government, and private laboratories are urged to open their doors to the public and provide children with a direct experience of working in that environment. National Science Week is well on the way to becoming an important nationwide event.

Need for Realism and Shared Effort

NSF will continue to fund carefully targetted programs that support both formal and informal science education at the precollege level. But NSF's role is necessarily limited.

Elementary and secondary education are principally the responsibility of some 16,000 school districts. And the principal responsibility for educational policy at this level rests with state and local governments. This is clearly where the responsibility should remain.

NSF's best use of its resources is to furnish examplary materials and stimulate the involvement and interest of others. It can also play the role of matchmaker to encourage the formation of partnerships among all the organizations--governments, private firms, teachers associations, and professional organizations--to further the goals of science education.

Conclusion

In closing, I would re-emphasize a sober appreciation of the need to improve the scientific and technological literacy of our citizens. Both our economic and our military security depend on it.

But in pursuing this objective, we must not allow ourselves to equate public interest with technical competence.

As the writer and educator Edmund Fuller remarked a few years ago to a student audience, there is a danger that they may become the best informed generation in history quantitatively, but also one of the worst educated generations.

"You could be cursed," he said to them, "with information without wisdom [and] data without understanding."

It is the responsibility of all of us to see that this does not happen.

ERICH BLOCH became Director of the National Science Foundation in August, 1984, following a long and distinguished career with IBM. He is the recipient of many national awards and honorary doctorates. His address is The National Science Foundation, Washington, DC 20550.

Bull. Sci. Tech. Soc., Vol. 6, pp. 146-151, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

TECHNOLOGICAL LITERACY: A NATIONAL IMPERATIVE AND BENEFIT

Cecily Cannan Selby

As Dr. Bloch's opening address has so eloquently expressed, our nation's ability to meet the challenges of its future depends greatly upon the scientific and technological literacy of its citizens. Your attendance at this meeting enthusiastically supports this conviction.

In its initial 1982 report, the National Science Board Commission Report on Pre-College Education in Mathematics, Science and Technology, identified three objectives for the educational dimension of this challenge. These are that our educational system, both formal and informal:

1. continue to develop and broaden the pool of students who are well prepared and highly motivated for ADVANCED CAREERS in mathematics, science, and engineering;

2. widen the range and increase the quality of educational offerings in mathematics, science, and technology at all grade levels so that more students would be prepared for, and thus have greater OPTIONS to choose among, technically oriented careers and professions; and

3. increase the GENERAL LITERACY in mathematics, science, and technology of all citizens for life, work, and full participation in the society of the future.

Thus, the Commission identified three foci for the nation's educational objectives: leadership talent, professional base and general literacy. Most importantly, it said that these objectives COULD be met! Evidence that all students could develop a USEFUL UNDERSTANDING of Mathematics, Science and Technology if early and appropriately introduced and skillfully taught was clear. Current NSF priorities follow the Commission's recommendations concerning the critical importance of the earliest grades, and appropriate and skillful teaching.

The National Academy of Sciences/National Academy of Engineering 1984 report on Secondary School Education for the Workplace added a critical new dimension to this educational vision when it reported, "Those who enter the work force after earning a high school diploma need virtually the same competencies as those going on to college, but have less time or opportunity to acquire them."

These are historic statements--and revolutionary ones: historic in melding goals of the long separated academic and vocational tracks in our pre-college system. Revolutionary in setting new objectives of "higher order skills" for ALL, repeat, ALL students. On this latter point all the various reports and studies of 1982/83 are agreed.

But, to move to the topic of the morning: how can our educational system, in all its diversity, meet these challenges? The Commission said that the children, the students, are ready. How do we meet their need? The challenge is formidable because we must deal with what is easy for children, but difficult for adults: CHANGE. You will recall that, on leaving the Garden of Eden, Adam turned to Eve and said, "My dear, we are living in a time of transition." For so many, change does mean leaving Eden.

My message this morning has the usual good news/bad news balance; not, I hope, an equilibrium model! Working totally for us are the range of benefits that technology can bring to education. Working against us is a range of attitudes and habits inherited from the historical development of science and technology in our schools. Current difficulties in reaching consensus (not compromise!) on teaching and learning strategies can be interpreted as arising from a tension etween the four educational movements that led us to today: liberal arts intellectualism, Jeffersonian egalitarianism and Jacksonian utilitarianism, and the student-centered development approach of progressivism.

Before Thomas Jefferson's leadership in committing the United States to free public education, the privately funded institutions established in the colonies were direct descendants of the aristocratic "liberal education" of England and Europe. The classics, literature, mathematics, and natural philosophy (science) were stressed. Initially, the program at public secondary and elementary schools in the United States followed this tradition but included some practical skills, following Benjamin Franklin's recommendations regarding "useful learning."

The Jeffersonian educational philosophy picked up on this liberal arts tradition. Coupled with the democratic philosophies of the time, this led to the policy that free higher education was for those who have the talent and motivation to benefit from it.

Next came the Jacksonian emphasis on utilitarian ends, which became reality with the founding of land grant colleges for agriculture and the mechanical arts under the Morrill Act of 1862. Elementary and secondary schools were joined in this utilitarian vocational thrust by means of the Smith-Hughes Act of 1917 and, later, The Vocational Education Act of 1963. Thus the separation of the practical from the theoretical developed.

The parallel development of the land grant colleges of the nineteenth century and the new emphasis on research in U.S. universities later in that century continued. The side-by-side development of utilitarian and intellectual liberal arts approaches continued and was successful in strengthening both the intellectual and technological base of the American economy and society. Indeed, for the most pat, the nation retained its confidence in the overall system until after World War II.

Meanwhile a more student-centered and developmental pre-college approach emerged before WWII following John Dewey's seminal research and writing. All that children bring to their learning was recognized and "progressive" education developed in a variety of forms. Patricia Alberg Graham suggests that the nation was able to move its focus from skill development for the NATIONAL good to personal development for the STUDENT good as it felt more economically and politically secure.

Following WWII came the nation's love affair with science. With the dramatic breakthroughs of fission and fusion, radar and semiconductors, physics captured the public's imagination. And technology, in all its dimensions, became perceived as the servant of science. The technologies that won the war (radar/sonar and nuclear energy) were, indeed, derived from science. Science finally made it as a status symbol. Let us remember that it had not been such before. And technology in pre-college education, but NOT in industry and in the military, was relegated to an "all other" status. Conflict between this direction and that of equal opportunity and self-determination in the 60's and 70's inevitable led to a relative decrease in populations prepared in what became accepted as "traditional" science education.

Now we have come full circle in proposing that "Technology must become more elite and science more common." Attitudes which moved from admiration for "Edisonian Research," trial-by-error invention, to depreciation of "non-scientific" approaches are showing renewed appreciation for the "technology first" inventor. This brief historical digression is to point attention to the long line of attitudinal development which must now be addressed--and changed.

The good news: There is an approach to Technology that could lead us to a melding of the four apparently conflicting educational trends already mentioned--and to, I believe, much more. It depends upon clarifying the differences and relationships between science and technology. It also builds upon the new receptivity to, and expectation of change brought by the simple PRESENCE of new technologies, notably computers, in schools.

From a historic, I move to a personal digression. Although I studied for three very happy years at an Institute of Technology, I hardly thought about Technology. I perceived myself as a scientist removed from those in the "applied" fields that were somehow dependent upon us scientists for ideas to apply! When I thought about technology at all, it was as some kind of applied science. Then, nearly a generation later comes the revelation! Thanks to the writing of M.I.T. metallurgist Cyril Smith, and a Yale historian, Derek deSolla Price, discussions at an NSTA meeting two years ago with Paul DeHart Hurd and Morris Shamos, and my new colleagues at N.Y.U. in industrial arts, and arts education I now see applied science as only one facet of the whole extraordinary human creativity that we call technology. You can call my revelation "The Midlife Crisis of an M.I.T. Coed!"

I prefer now to describe Technology as both the process and the product of human endeavor to develop tools and systems to enhance human capacity to do, to see, to feel, to smell, to think. This has been a creative endeavor, a "creating" endeavor, unique to humanity since the dawn of its history. Not all the motivation to create comes from perceived physical, economic or political need. Some arises from untrammeled curiosity. Jeremy Bernstein makes an eloquent case for scientific and technological literacy on the basis of human curiosity alone. Some arises from aesthetic need. Incorporating the various meanings for "Techniks" and "technique" from European culture, technology can be observed by its products or by the processes that make the products. It can be things, or the system to make them. I find Stephen Kline's definitions in the recent S-STS newsletter consistent with this approach. It is my understanding that anthropologists agree that human beings everywhere and at every time have organized and controlled the resources of the natural world to do work and make things.

The human being is thus at the center of technology, having made it all. Why not, then, consider technology a humanity? Through enhancing the power of the senses, the process and products of technology enable and expand AESTHETICS and COGNITION. Aesthetics and cognition, the essence of learning: does not, then, technology have the potential to empower learning? In "Mindstorms" Seymour Papert proposes that aesthetics should be as intrinsic to mathematics education as it is to mathematics.

If we can agree upon these distinctions between science (the non-human, the Creator-made, if you will) and technology (the human-made), I suggest that we can give new and needed direction to curriculum and teacher training. The human-made can be appreciated concretely, the creator-made only conceptually, abstractly, theoretically. Science can and should stand alone, as do the Arts, Philosophy and Religion as ways of looking at the Universe: separate and equal. Technology intersects all fields of learning, providing tools and systems for looking and interpreting, particularly for the Arts and Sciences. It is needed for and developed by medicine and theatre, manufacturing and management as well as by science. Architecture, through the ages, has been the quintessential interdisciplinary technology--including also the important technologist/artist/ patron relationship. With the presence of computers now able to work with and integrate virtually all technologies inter-relationships between all technologies, both process and product, have become more evident.

Rather than bewail C.P. Snow's "Two Cultures," I suggest that we honor four cultures: The Arts, the Sciences, Philosophy and Religion. Technology and the humanities intersect, interweave and unite all. For all those who seek a unifying factor in curriculum design--for teacher as well as student courses of study--technology and the humanities are ready, willing and able! Indeed, this may be a most appropriate goal for Science, Technology and Society programs: to relate Technology and all the Humanities as integrators and interpretors of the more independent studies of Arts, Sciences and Philosophy. I suggest that clarification of these relationships can help move the invaluable and prescient initiatives of the STS movement into the mainstream, as this Conference promotes.

There is more to my good news. Technology approached as a human-centered and culture-centered activity should help us reach all students. The study of what men and women in every culture have made, in systems and things, should be accessible to the understanding of other human beings. The systems and products are tangible; they can be seen, smelt, heard, touched. Men have, generally, made different things than have women; Asians than Africans. But they have all been technologists. Anthropologists tell us that women were the first agricultural technologists. From Jane Goodall's observations of female chimpanzees we know that they use tools longer and more frequently than males! Readers of Evelyn Fox Keller's, "Reflections on Gender and Science" will not be surprised to discover that technologies used for illustrations in textbooks are those of interest to and most understood by the caucasian male authors and publishers but not to all students. Our technology education should include the technology of the kitchen and the farm, the subway and the studio, if we are serious about access to all. A culture-free and gender-free technology education could offer opportunities for all students to satisfy and thereby develop their curiosity with material accessible to their immediate understanding. Student minds and hearts thus opened are then available for improved learning in every domain.

What other benefits can technology bring to teaching and learning? It involves trade-offs. Trade-offs are implicit in the choices, the decisions about how to make something. Consideration of values and risks underly choices. Risks are related to considerations of social, political and economic costs. Man/woman the creator is always involved with valuing. The teacher, the student, can get personally involved with value relationships and the choices they provide. Should something be made big and slow or small and fast, cheap and imperfect or expensive and perfect? Should it be made? Is there anything made, from a saucepan to a violin, a rocket to a computer that does not involve choice and thus the values of the creator? What a superb tool technology thus provides to the teacher who wants to deal with values, informed decision-making and also deal with the world around and accessible to the student?

Technology involves systems, understanding of which is transferable to all fields of learning. Learnings about feedback in electric circuits can be applied to psychology and to history. Observations of traffic flow can be correlated with fluid dynamics and the circulatory system. Student confidence in learning is enhanced by observing the transferability of structures and systems and their associated behavior.

Technology involves innovation. One of the paradoxes I find in our current educational deliberations is that innovation for technology transfer is seen as the security blanket of the nation's future and yet it does not appear in educational objectives. If our learning in all subjects involved the technology of these subjects, consideration of innovation would have to be intimately involved. The innovation is implicit, again, in the choices of the Creator. The laws of motion give the student no opportunity to innovate EXCEPT through technology.

Technology involves the brain and the senses, the affective and the cognitive. The "hands-on" approach of the best museums and other informal education opportunities and the best of science educators builds on this understanding. As we look at how technology expands the aesthetics of all the arts, we can see how technology can expand student's motivation for learning through aesthetics. As technology education is explored in this way it will emerge as a catalyst for aesthetics education and all this can mean for developing human potential--creatively and innovatively.

My remarks so far have demonstrated to you that this scientist is not yet a technologist! I have given only theoretical answers to the questions of "How." I have attempted to outline the many benefits a freshly conceived technology education can bring through the factors inherent to it: interdisciplinary, affective, innovative, and through the factors involved in its creation: trade-offs, aesthetics and systems. I have tried to demonstrate that a comprehensive human-centered approach to technology, with clear distinctions from science, can lead us to our new educational objectives. And what are these? A focus on all students; strategies for different learning styles; teaching for creativity and innovation as well as basic skills; improved access for females and minorities; and, for teachers, students and parents alike, a vastly increased interest and confidence in understanding technology and its related fields of mathematics, science and the arts.

To move on these assumptions and objectives requires a true consensus on needs, means and goals. Agreement of those in positions to communicate and to lead is the necessary first step to widespread adoption of activities and programs. The convenors of this Conference are to be commended for their initiatives in this direction. If the position of technology in schooling is assured and clarified according to the criteria just reviewed new directions for teaching and learning strategies will open up.

Existing partnerships with industry, the military and the informal education of youth agencies, museums and the media can be much more productive. With the topic of technology new to the curriculum, it should be easier to introduce it without threat to existing personnel and programs. The NSB Commission suggested that a technology course be required in grades 8 or 9 and that schools turn to local industry for help in setting it up. It urged that technology studies be integrated throughout the curriculum, K-12. In communities small or lage, there is no lack of civilians with technological knowledge to help: From the dental technician to the civil engineer, the car mechanic to the retired airline pilot. With respect to large industries, particularly those with products that can be useful in schools, we must insist that they work with educators as partners, not consumers. Educators must be directly involved in the design of hardware and software, not asked to buy expensive material needing major adaptation for educational use.

Museums and technology centers are natural partners. Thanks to the Association of Science and Technology Centers and to the NSF program in Informal Education, educational programs in museums are blooming, as is the development of locally supported new museums and technology centers of all shapes and sizes nationwide. One vision I have is of low budget technology centers, with contributed equipment, available for family learning in large housing projects and shopping centers. Indeed, with the problems current schools have with security and financial resources to remain open after school hours, community-based technology centers may be essential partners for future school programs.

The media, particularly through local programming and VCR and videodisc software, could play an equally vital and complementary role in supporting and extending school technology programs.

In communities where schools have a strong Industrial Arts component, involvement of these teachers and their laboratories may be the most valuable and untapped source. It should be helpful for other academic high schools to know that New York's Stuyvesant High School, so notable for its academic achievements in mathematics and science, has maintained its industrial arts requirement. A Nobel Laureate and several other senior scientists who attended Stuyvesant have told me that their technology laboratory opportunities there proved to be invaluable.

It has been said that an optimist is one who sees the future as uncertain. I am an optimist and see the future of technology in the schools as uncertain but, thanks to efforts of so many here, certainly not zero. My optimism arises from the possibilities that a NEW look at technology, all it is and was and could be, could bring a fresh outward and open look to school systems. Since no one in the system is supposed to be, certified to be, an expert in technology, then all the partnerships mentioned above can be more productive. The professional expertise of the teacher in understanding students, learning and resources can be reinforced, at the same time, the role of outside resources clarified and strengthened. The door left half open when computers entered can become a wide-open portal for so much I have reviewed today. Above all, we must develop a clear and loud consensus on overall guidelines for goals and means for our youth in their schools.

From my youth rich with exposure to Victorian poetry, I remember a line from Ralph Hodgson, "I, a stranger and afraid in a world I never made." The "bottom line" of my recommendations is that our educational system, both formal and informal, find ways to open the human-made world to understanding so that students will not feel stranger within it. There is another Hodgson that speaks to the curiosity of youth, "Let us continue and struggle to maintain youth's curiosity and thus its optimism in dealing with the current and in creating the future human-made world."

CECILY CANNON SELBY is Adjunct Professor in Science Education at New York University, School of Education, Health, Nursing and Arts Professions, 50 W. 4th St., New York, NY 10003, where she is engaged in teaching and research. She was Co-Chair of the National Science Board's Commission on Pre-Collegiate Education.

Bull. Sci. Tech. Soc., Vol. 6, pp. 152-158, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

COLUMBUS AND COPERNICUS

Governor Richard D. Lamm

I should like to talk today about Columbus and Copernicus, and the new world of public policy into which I believe we are moving.

Columbus discovered and described a new world and I, a political Columbus, should like to describe for you the new world of public policy. I may, as Schopenhauer once observed about all men, be confusing the limits of the world with the limits of my own mind. So, I speak in full recognition that I might be absolutely wrong. In fact, I speak in hopes that I will actually help history prove me absolutely wrong.

My vision of the public policy longitude and latitude of the new world we face is not the normal political description, and the course I would choose to avoid it is not the normal political prescription. Adlai Stevenson said, "Americans are suckers for good news. Given the choice between disagreeable fact and agreeable fantasy they will choose fantasy every time."

We are sailing into a world rife with tension between budgetary constraints and social and political demands.

For the past fifteen years, our economy has been staggered by a number of external shocks and internal inadequacies. Continued growth of the economic pie, which is so necessary to democracy, is simply not happening. In the early days of my career, politicans could distribute justice by dividing a growing economic pie. Now the pie has remained roughly the same size. The average American made less money--adjusted for inflation--in 1983 than he did in 1973. We face a new world of international competition in which we are exporting our wealth. In 1970 the United States produced 40 percent of the world's gross national product: by 1980 it was down to 30 percent and falling.

Exploding deficits, debilitating trade deficits, runaway health and pension spending threaten our future. We borrow $.20 out of every federal dollar we spend.

The new world marketplace has already moved millions of jobs offshore and threatens to move millions more while our successful rivals take an ever-greater share of the world market away from us. Their exports grow while our imports grow. U.S. productivity growth is the smallest of any industrialized world.

Other industrial nations have pre-empted our leadership in technological innovation in many areas. They spend on research and development while we scrimp. They train engineers while we train lawyers and real estate salesmen. They spend money on preserving health while we spend money on training doctors and treating illness. The engineers they graduate go to work in the domestic economy to build better exports while forty percent of our engineers and scientists work at building a defense system. They build factories while we build excessively opulent homes. They emphasize responsibilities when we emphasize rights. The invest in their future as we mortgage ours.

Our system is not structured for long-term success. It is structured toward long-term decline.

I, as captain of a small, but beautiful ship called Colorado sense that there is a gathering storm that is about to break upon our society. There are serious internal contradictions in a society that no longer makes the radios, black and white tv sets, or video recorders that it originally invented, yet pays for everyone on kidney dialysis. While moving our basic value-producing industry offshore, we continue to manufacture artificial hearts and MX missiles. Our education system deteriorates and our infrastructure disintegrates. The United States spend more on the research and development of the MX missile than General Motors allocated to its entire research budget. The Department of Defense spent more on R&D on the B1 Bomber than the whole steel industry invested into R&D. We are skewing our entire economy toward the military and toward health care, and in doing so we are sowing the seeds of a major crisis our children will reap.

A debt bomb threatens to explode our economy. Consumer debt is rising at a 20 percent annual rate, which means that total consumer debt doubles every three-and-a-half years. Our federal debt has doubled in the last five years, and the United States has gone from the world's largest creditor nation to what is projected to be the world's largest debtor nation by 1990. American's top nine banks have loaned more than 100 percent of their shareholders' equity to four Latin American countries--Mexico, Venezuela, Brazil, and Argentina. Our farm debt is $200 billion, which is larger than the debts of Mexico and Brazil put together. The FDIC has only $13 billion to protect bank deposits of $1.3 trillion, or a penny for every dollar on deposit.

By ignoring or deferring our problems, we are painting ourselves into a fiscal corner. We will have no flexibility--no magin of error--for the next recession.

Even as we have let our debt grow and our economy falter, we have institutionalized enormous demands against it--future social promises and costs that cannot possibly be met. Borrowing from the future to sustain a lifestyle we can't afford, and simultaneously neglecting our economic machinery is like sowing a minefield in our own front yard. We will not step on every potential mine, but it would be a miracle if we got very far into the twenty-first century without stepping on some of them.

In the past twenty years of stewardship, my generation of politicians, businessmen, scientists, economists, engineers, and educators has allowed America to lose its lead. Self-indulgent and only too willing to sign promissory notes, we have been poor trustees of our nation. On the tablet of history, the honest sailors will have to confess that "it happened on our watch."

Let me tell you a parable: The U.S. fleet was on the high seas. All of a sudden a blip appeared on the radar screen. "Tell that ship to change its course 15 degrees!" said the Admiral. The radio man did and the word came back on the radio, "You change your course 15 degrees." "Tell that ship that we're the U.S. Navy and to change its course 15 degrees," said the Admiral. The radio man did and the word came back again, "You change your course 15 degrees." This time the Admiral himself got on the radio and said, "I am an Admiral in the U.S. Navy, change your course 15 degrees." The word came back over the radio, "You change your course 15 degrees, I am a lighthouse!"

Like the ancient mariner I tell everyone I can grab that America is becalmed--motionless in the tide of history, and we are drifting toward the shoals. We are committing the same economic sins that sank earlier civilizations.

I hear the thunder. I see the gathering storm.

Copernicus

Copernicus asked the right questions. A heretic, he dared suggest--instead of the sun going around the earth, might not the earth go around the sun? By asking the right questions, he essentially solved the problem. As the Greeks said "to know all to ask, is to know half."

No Solutions Without Pain

America is faced with a new political reality. We have undertaken obligations beyond our ability to deliver. Our compassionate goals exceed our fiscal reality. Our position in tomorrow's world of international affairs will depend on our ability to acknowledge this fact and to muster the collective will to respond to it.

The playwright Belloc warns us, "Truth, like roses, often comes with thorns." The "thorns" of this new world of public policy is that all problems do not have universally compassionate solutions. There will be people who do not get a transplant, or an artificial heart; hardworking immigrants who will not be admitted to the United States; medical care technically available but fiscally undeliverable. We must have the social maturity to recognize that we can't solve all problems or even avert all tragedies. We are faced with a series of Hobson's choices and need yardsticks to choose among worthy people. Our national survival depends on it.

We have projected $200 billion deficits for "as far as the eye can see," constructed a health care system that grows at three times the rate of inflation; military retirement systems that allow 26 percent of those receiving pensions to retire while still in their 30's (all with indexed pensions and health care) and a Medicare system that promises enormous future costs. By not making hard choices to reform these systems we are dooming our children to tragic choices. By trying to make today a dream we make tomorrow a nightmare.

I believe much of the fault is because the United States has no heritage of having to make tough decisions. We bite no public policy bullets. We have deluded ourselves into believing that all problems can have compassionate solutions; that all stories can have happy endings.

Sadly, they can't.

As columnist George Will points out, the 1985 U.S. deficit is more than the gross national product of 158 of the world's 167 nations. Our current year's deficit exceeds the total amount of money spent by the United States government just 13 short years ago. It has grown from approximately 1/2 of one percent of the gross national product to approximately 5 percent of the gross national product. The United States is currently borrowing $.20 out of every dollar that it spends. The interest alone we spent to service the federal deficit exceeds the amount of money that Lyndon Johnson spent to run the war on poverty, the Great Society, and the Vietnam war simultaneously. It will not be solved without pain, without hard choices, and without cutting some benefits currently paid.

The federal deficit is felt acutely by every citizen. The government borrows from the same pool of money that you or I do for houses and student loads; the same pool from which our manufacturing sector borrows money to reinvest in productivity. This stiff competition for limited dollars raises the cost of borrowing them. Interest rates climb, and foreign countries, seeing a relatively safe investment and profitable return, buy up our dollars. Massive foreign investment bids up the value of the dollar vis a vis other national currencies. The result? U.S. goods and manufactured products are priced right out of the international marketplace. Look at our mining, steel, and auto industries. Look at our farmers.

I suggest that the only honest political platform is "I'm going to raise your taxes. I'm going to cut your benefits, I'm going to have to reform your institutions." The size of the deficit clearly precludes easy solutions. They will mostly involve pain, and as we have recently seen, a larger exercise of political will than currently seems to be available in Congress. Military spending will have to be cut, social programs will have to be revised, and taxes will have to be raised.

The United States has traded its creditor status in the world for a greater perceived sense of military security. A country is no more secure militarily than its economy is strong and stable. If we ruin our economy building weapons systems like Star Wars, we will have built a Maginot line. As did the French before World War II, we will heavily and at astronomical expense fortify ourselves with a system that does not work.

We must reduce the rate of military spending.

As Dwight Eisenhower said, "The problem in defense is how far you can go without destroying from within what you are trying to defend from without."

The hardest and most politically volatile of the equation to cut the deficit is, of course, to cut benefits. But I suggest that there are yardsticks that can dramatically cut benefits without hurting one deserving recipient. It involves means-testing our entitlements programs, and focusing our money in serving those in greatest need.

Consider, for example, that currently over 700,000 people who received Social Security benefits earn over $50,000 a year in other retirement income. They have a medium income of $63,000 a year without including what they receive in Social Security payments. One-quarter of all Social Security payments go to people with total incomes of over $25,000 a year which is equal to the average income of a family of four in the United States.

The concept is mind-boggling--taxing the working poor at rates that are now large and growing and sending one-fourth of all of that money to people who have higher incomes than the vast majority of the contributors.

One possible way to approach the problem would be to tax entitlement programs such as Social Security and Medicare so that low income recipients would pay nothing and yet the governmental benefits paid to high income recipients would be taxed. The first step of this was taken two years ago when 50 percent of the maximum benefits were included in the taxation of the highest income producers. If we would do the same thing with Medicare, which would allow low income people to pay nothing while taxing Medicare to high bracket taxpayers, billions of dollars could be saved.

The United States has farm programs such as the recent PIK program which are allocated on acreage rather than need of the farmer. Half of the $21 billion which was paid out in 1983 went to the largest 10% of our farmers not to grow crops.

Similarly, the federal government budgets for "tax expenditures"--the money that the government does not get because of the tax exempt status of mortgage revenue bonds and interest payments on mortgages. The exemption for mortgage revenue bonds costs $400 million a year, and the homeowners tax preference eliminates $25 billion out of the federal treasury. These benefits are not targeted toward the poor or the needy, but often give homeowners tax shelters for vacation homes and clearly set up a policy in America encouraging an overconsumption of housing. While studies show that less than 30 percent of today's 30-year-olds will be able to purchase their own home, the rest of us have unlimited and untargeted tax deductions for our homes. A modest cap on mortgage interest and real estate taxes could easily preserve the vast amount of deduction for middle and lower class people while at the same time saving the Treasury billions of dollars.

Another area crying out for reform is military pensions. The most common retirement age for enlisted men is 39. The most common age for retirement of officers is 43. Nine out of ten military pensioners are working age and 26 percent of those who retire, retire while still in their 30's--all with index pensions and all with medical care. Military pensions are three times more lucrative than private pensions, plus military pensioners get free medical care. The bill for pensions has shot up six times larger than the overall increase in defense spending over the past 20 years. Retirement budgets were two percent of the Pentagon's budget in the early 1960's and they are now 6.5 percent and growing. Military retirement is the second most expensive federal entitlement program coming directly from general tax revenues.

We will have to reform our institutions. Yesterday's generosity exceeds today's fiscal realities. Today's politicians are in the unenviable position, not of granting additional programs, but of taking away ones previously granted. But the option of doing nothing will have much larger social, economic, and political consequences.

Take, for example, our health care institutions. The most important reality to accept in dealing with health care is that we can't go on as we have been--allocating increasing percentages of GNP to health care.

Health care costs are eroding our domestic goals, our international markets, and are reducing our ability to compete with foreign companies. As Joe Califano, Jr., has said:

> "In 1984, Chrysler's health care costs will exceed $400 million, making the Blues Chrysler's single largest suppliers. That's more than $1.1 million each day ... This year, Chrysler must sell about 70,000 vehicles just to pay for its health care bills."

He points out that Chrysler's health care cost per active employee is 400 percent higher than Japan's Mitsubishi Motor Corporation ($815 vs. $5700) and that the gap is likely to increase. The Big Three auto companies spent about $3.2 billion for health care last year.

In 1950 government spending for health care was 45.9 percent of that of education; by 1984 it was equal to all government spending for education. More hospitals come at the expense of more education, or more infrastructure, or more housing. America has other societal values in which it must invest. We have roads to build, infrastructure to repair, educatio nsystems to rejuvenate. We must retool and re-industrialize America.

The health care spending numbers are awesome--in 1984, over one billion dollars a day. Health care in 1983 took 10.5 percent of GNP and was on a growth rate that could easily be projected to consume 20 percent of GNP early in the 1990s. Health care has grown at a compound growth rate of 10.6% per year since 1950. Just 20 years of the recent rate of increase would have America spending 40 percent of our GNP on medical costs--an absurd and devastating amount that would have long before crippled our economy.

Victor Fuchs finds the key element in current concern over health care spending "The divergence between what is good for the patient and what is efficient for society as a whole ..." We are not now asking those questions.

But we are choosing today. By not confronting these realities we choose by default, indirectly with no reason and no forethought. As theologian Harvey Cox warns, "not to decide is to decide."

We all want excellent health care: But should one be allowed to endlessly treat a terminal disease if the marginal benefits are far exceeded by the costs? How much heroic medicine and how many artificial organs can we afford?

Our love affair with expensive new technology is partly responsible for exploding health care costs. A recent study by the Office of Technology Assessment found that increased use of technology accounts for nearly one-third of the increase in Medicare costs over the past five years.

But it is hard to resist such life-giving miracles as transplants and artificial organs when the victims are so visible. The medical profession and the media have glamorized transplant surgeons and have turned a handful of desperately ill people into celebrities. We allow Barney Clark and Mr. Schroeder--both heavy smokers--to damage their hearts with subsidized tobacco and we rush to fix them: but we do nothing to stop subsidizing tobacco, not nearly enough to screen for hypertension, very little to emphasize the relationship of heart trouble to diet, stress or lack of exercise. We support the visible "wonders" of health care but ignore the invisible prevention that could save far more lives. One expert observed, "It's as if the March of Dimes threw all its resources into iron lungs instead of helping Jonas Salk develop polio vaccine."

Stalin recognized this principal in his cruel rule "One man's death is a tragedy, a million men's death is only a statistic."

If we can't do everything, and we can't, we should spend our money intelligently where it will buy the greatest amount of American health. That would clearly not be on artificial organs or transplants for the few, but on preventive health care for the many.

The United States faces an aging crisis. America is getting older as we allocate more and more of our resources to programs for the elderly.

In 1900 people over 65 made up four percent of the population. By 1985, it was 11-1/2 percent of the population and by the year 2000 it will be 17 percent. In 1984, for the first time in history, there were more people over 65 than there were teenagers. By 1990 there will be 31 million elderly, while the teenage population will have shrunk to 21 million.

This will have a profound impact on public policy. Public expenditures for the elderly are approximately three times the public expenditures for young people. Poverty is decreasing among the elderly and increasing among young people. The elderly vote, they vote proportionately more than any other group. We have tilted our whole system toward those who vote. In 1970, 16 percent of those under 14 lived in poverty compared with 24 percent of those over 65. By 1982, the situation had been reversed: 23 percent of children lived in poverty compared with 15 percent of the elderly.

Anna Kurtz of the University of Chicago asked the painful question, "The question isn't whether we have given enough to the elderly, the question is have we given too much."

We cannot build an enduring future by neglecting our young. We need to strike a balance between our care of those who need it today and the promise we made for the lives of those who will inherit tomorrow.

In addition to reforming many of our basic programs, politicians will have to learn to say no to a wide variety of well-intended, but inefficient, programs if we are to close that deficit gap.

Can we afford to spend $8 billion to put a lift on every bus in America when St. Louis, for instance, reports such a program would cost $600 per person per ride? When in Philadelphia this costs $300 per person per ride? The Congressional Budget Office estimates that by using vans we can serve 3.5 times as many handicapped for one-sixth the cost. I am not disputing the worthiness of the underlying goal. Of course, we should provide transportation for the handicapped. But just as handicapped citizens have a right to be transported, so other citizens have a right to make sure that that transportation is provided in an efficient manner. In an America of more limited resources we must learn to be both compassionate and efficient.

Capital is the stored flexibility we as a nation have to meet the future. We can spend it wisely or we can dissipate it. How we spend it is going to determine what kind of America we leave our kids. We can invest it in superfluous health care and inefficient pension programs or uneconomical wheelchair lifts, or we can spend it retooling and re-educating America, retraining our workers, rebuilding our infrastructure, and investing in the talent and promise of the generation who will inherit the country from us.

I know of no democracy in history that has been able to reform itself from its excesses. Our times are a test of democracy--can we reform our systems, can we alert our citizens to creeping crises which are equally as profound, but much harder to rally people against. One of the major dilemmas that we are in is that the best public policy is often the worst politics. Our political process and humanitarian traditions and our media-drive humanitarianism negates often the exact policies which are virtually necessary to solve our country's economic and social problems. We are paralyzed by our traditions, crippled by a mass mind that thinks that prosperity in America is a law of nature. It is not.

Our nation, like Faulkner's southern family, is reflecting on our past glories while our current situation deteriorates. Our political debate is a dialogue between the deaf and the dumb. It is extremely doubtful whether our institutions are now equal to the tasks that lie ahead and to the new world into which we are moving.

But this fate is not inevitable. Twain found that those civilizations that died did so because they were incapable of making a successful response to some overwhelming challenge that confronted them. But we are capable. That is our task ahead--to confront these new realities and to muster the political will to conquer them.

Thank you very much.

RICHARD D. LAMM *is third term Governor of the State of Colorado and one of the most articulate elected officials on matters regarding science and technology. His address is Executive Chambers, 136 State Capitol, Denver, CO 80203.*

Bull. Sci. Tech. Soc., Vol. 6, pp. 159-162, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

COLLEGES AND UNIVERSITIES VERSUS SCHOOLS: SHALL THE TWINS MEET?

George Bugliarello

My assigned task is to look at the issue of scientific and technological literacy in terms of what colleges and universities are doing (or not doing). I would like to do so through several points.

The Situation Today

1. In the same way in which we are talking about supply-side and demand-side economics, we could talk about supply-side and demand-side technological education.

Demand-side education is motivated to respond to specific needs--for example, to prepare the citizen for employment in a society, in which a knowledge of technology is becoming more and more needed at all levels of skills, whether one works in industry, agriculture or in the service sector.

Supply-side education, on the other hand, does not respond to specific needs, but rather it creates them. It educates the citizen to learn to ask questions and to acquire a new sense of the meaning of his or her life through an understanding of the choices made possible by technology.

2. At this moment there is confusion about the two kinds of education, in colleges as well as in high schools. We engage in both kinds of education, but are guided more by tradition than by recent analysis. I say recent analysis because things change so fast in a technological society that what we may see as demand-side education on one day, can rapidly become supply-side education the next.

Take, for instance, calculus. Why do we learn calculus in college? Few professionals, including engineers, use it after graduation, and if we need calculus, we can rely more and more on computers to do calculus, once we understand its key concepts.

So, at my university, we have started asking the question, "Why do we teach calculus?" Is it for the specific needs of the professionals? As I have indicated, that need has changed with the computer. Is it for a cultural reason, to be more knowledgeable about math (a supply-side argument)? But then, if the answer is yes, the next question must be asked, "Is calculus the best subject in order to know more about math? Is one more course in calculus better, for instance, than one course in topology or in the theory of sets?" Or, and this is the third alternative, do we teach calculus, as is often believed, primarily as a way of fostering reasoning? If so, is this the best way to teach reasoning, or are there other possibilities?

Please believe me, I am not crusading against calculus--quite the contrary--and the answer to each of these questions may all told be: calculus. But I am simply bringing up the case of calculus to suggest an example of the confusion between demand- and supply-side educational motivation.

3. While most colleges have been involved for quite some time in continuing education, so that they have at least one important vehicle for communicating with the adult

citizen, they have paid little attention to high schools and elementary schools--except in terms of the teaching methods studied and taught at teachers' colleges. So here I shall tend to focus primarily on the relationship of the colleges to elementary and high schools.

4. Viewed from the schools, the colleges must appear as enclaves to be penetrated by the high school graduates, and otherwise as institutions that are quite uninterested in the schools. To the schools, the colleges appear to practice--and indeed, they do practice--a "hands-off" policy in terms of what is taught in the schools--except for what is needed for admission to college.

Viewed from the schools, furthermore, the colleges have undoubtedly propagated a view of science through a prism of specialization and complexity. Perish the thought, for instance, that we in the colleges would say to the high schools, "learning biology or physics is far less important than learning how to look at nature in general, and how to ask questions. Nature is indivisible." The penchant for complexity we have encountered already in the case of calculus. I strongly believe that it is possible to convey the essence of a scientific or technological subject in a few hours--if one does not insist on extensive coverage. Essence is more important than extension.

Above all, the message emanating from the colleges toward the schools is one that has failed to stress almost totally the man-made. The man-made--that is, technology--as a process, as a creator of new environmental niches, as an extender of our senses, our muscles, our mind, is viewed by most colleges as the province of the engineer, rather than as a burning concern of every citizen. Perhaps this view stems from the fact that while there are in this country over 4,000 colleges and universities, there are only 300 engineering programs, most of which have not been involved or interested in general school education. One of the most notable exceptions has been the pioneering efforts by Ed David, John Truxal and Joe Piel in the sixties, with their book "The Man-Made World." That is a great book, still going strong, that needs to be embedded in a whole system of college-school interactions.

5. The colleges and universities themselves, in general, do not seem to be very clear at this moment, in their own minds, as to the essential architecture of the educational process. While a great deal of debate thrives perennially in colleges about the relationship of education to ethical values, or about the need for one given subject versus another, or about the amount of choice the student should be given over the curriculum, there has been little concentrated on threr critical issues that must be at the core of the educational process, in the colleges as in the schools.

The first issue is how to deal with the mounting amount of knowledge that is being generated. More specialization or more courses are not necessarily the answer, or the only answer, as this excludes the citizen with a general education, and it even shuts out professionals outside of a given specialty.

Secondly, there has been little concentrated effort on how to foster creativity. It is a common place, by now, that focus on creativity is steadily reduced as we move from kindergarten to college to graduate school: in this educational progression creativity is replaced by accumulation of knowledge and by increasing focus on analysis.

Thirdly, even in the domain of analysis--of logical thinking--there has been little concentrated and systematized effort on how to take full advantage of artificial intelligence and its relation to reasoning.

What Can Be Done?

So, given this situation, what can be done by colleges and universities to foster technological literacy, beyond the more traditional activities of continuing education and beyond the ritual wringing of hands?

I shall not attempt to discuss here what we may mean by technological literacy, except to reiterate the concern expressed by many in this Conference, that too often we tend to equate it with the ability to program a computer, rather than with developing perspectives on technology.

So, what can be done? I believe that much can be done. As an example--not a perfect one by any means--I would like to mention a number of activities which we have initiated recently at Polytechnic University.

a) A Center for Philosophy and Technology has been established, probably the only one of its kind in the country, under the leadership of Professor Carl Mitcham, who will participate in the next session in this Conference.

b) A totally new undergraduate curriculum in the liberal arts has been established with a grant from the Mellon Foundation. The curriculum is focused on our life as shaped by the interaction of biological, social and man-made entities.

c) We are publishing a journal, called "Technology and Society," under the aegis of Pergamon Press, with the goal of reaching the intelligent layman. The journal addresses technological issues, but without a single formula, and has explored topics such as biotechnology, nuclear waste, science advice to the President, macro-engineering, and technology transfer, just to name a few.

d) For a period of time, we presented on a commercial tv channel, a one-minute explanation of a significant technology or scientific story, as it appeared in the press the preceding week.

e) In collaboration with high school principals and district superintendents from three districts in Brooklyn whose populations are predominantly Black and Hispanic, we are designing a working program to upgrade the math and science curricula in the public elementary and high schools, and developing a program and curriculum for teachers of these grades, so that they will be able to better guide the student.

f) We are sending a number of our best students (who volunteer for it) to various high schools, to assist teachers with establishing lab experiments, programming computers, etc.

g) Above all, the most ambitious enterprise we have undertaken, is to develop a close partnership with a high school, Brooklyn Tech, and another college, Pratt Institute, to help upgrade the science and technology knowledge of high school students. We started with Brooklyn Tech because of our historical ties, and we are planning to extend this to other high schools. The results have already been very gratifying, with Brooklyn Tech students placing fourth, for instance, among the semifinalists in the last Westinghouse high school competition.

h) In the area of curriculum planning, we intend to benefit from the project 2061 of the AAAS, of which I happen to chair the Panel of Physical Science and Engineering. The major effort in that Panel is the quest for key concepts that can enable a high school student, or an educated adult, to overcome the bewildering complexity and specialization of traditional teachings of science. We are seeking to identify some fundamental connections between disciplines made evident by these concepts. Examples are the connection between energy and materials or between energy and information, and the examination of how different availabilities of energy, materials and information have shaped societies--from the energy-poor societies of antiquity, to the societies of the industrial revolution, to today's information and post-post-industrial society.

Conclusion

The fact is that, once we begin to focus on the issue of technological literacy as an important goal for colleges and universities, we see that there is so much that can be done, from the development of new disciplines, such as the philosophy of technology or socio-technology (the study of the interfaces of society and technology), to the networking, physically and organizationally, of universities with schools and with the rest of their community.

The bigger, more ambitious projects are clearly a matter of national or regional policy as well as national or regional investment, but there is much that we can do on a more modest level, essentially with the resources that we have.

GEORGE BUGLIARELLO, *President of Polytechnic University, is a distinguished engineer and educator long involved in technology and society affairs. He is Editor of Technology in Society and Associate Editor of The Bulletin of Science, Technology & Society. His address is President's Office, Polytechnic University, 333 Jay St., Brooklyn, NY 11201.*

Bull. Sci. Tech. Soc., Vol. 6, p. 163, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

THE RATIONALITY OF TECHNOLOGICAL LITERACY: INTRODUCTION TO SECTION ON CONCEPTS AND MEASURES

William F. Williams

In another article in this volume Joe Haberer argues that literacy, in its generally accepted sense, must and should precede technological literacy. I accept that. I believe that I am literate in that general sense, that is to say I can read--both English and American--with understanding and think that I can write so that I can be understood. I am not so sure that I am literate in the technological sense, because I am not sure what technological literacy is or how I can attain it. To define what science is is difficult enough. That being so, to satisfy ourselves that we have scientific understanding is doubly difficult. To define technology--containing some knowledge and understanding of science--is that much more difficult again, and the understanding of technology in all its widespread and complex interactions--and that presumably is what we mean by technological literacy--is obviously going to require a lot of hard and careful thinking.

When we reject the universality of science, the belief that science produces a set of truths which apply to all men (and possibly women) at all times and all places, then we have a problem. If we reject the idea that technology is just the applied form of that same universal science, neutral in its content and equally applicable in any context, then we have a double problem. If we campaign for technological literacy, what do we mean by technology and how is that meaning altered by the context. And does it mean different things to different people. What is it to be literate and how is that linked to the understanding of science?

The five papers in this section, taken together, give a feel for the size of these questions, their inter-relation, and the complexity of the answers.

Steve Kline describes a hierarchy of constitutions, and maps onto that hierarchy the disciplines, including the sciences and technologies, into which we organize knowledge. From that base he asserts the necessity of multi-disciplinarity and demonstrates the inadequacy of reductionism. It is not an easy paper, but understanding and wisdom are not easy. I have deliberately put it first because I believe it helps to put what follows in perspective. Read it, read the other three articles, and then read Kline again.

DeVore adopts a quite different approach, analyzing the question of technological literacy from a taxonomic viewpoint: a very thorough, careful look at its dimensions, showing the awesome extent of what we are trying to do. Smalley offers one initial test.

Miller and Layton describe two attempts to take technological literacy to the people. A dominant theme which ran through the proceedings at Baltimore was the need to make more--ideally all--citizens technologically literate. Only then will they be able to exercise some democratic influence over many of the issues which concern them. Sitting on our posteriors, talking to and at each other in academic gatherings is not enough; we must affect that far larger audience. To achieve that we must be able to measure present levels of literacy in the population, say what we mean by it, determine what it means for different individuals and different groups, find out what interest them and how to engage their interest. Neither Miller nor Layton would claim to have done all these things but their papers describe two different starts on the way. Without a start we will never get there; without a start we will never understand where we are going. Their papers show that the public has a lot to learn about technological literacy--and so have we.

Bull. Sci. Tech. Soc., Vol. 6, pp. 164-187, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

THE LOGICAL NECESSITY OF MULTI-DISCIPLINARITY: A CONSISTENT VIEW OF THE WORLD

Stephen Jay Kline

Abstract

For three hundred years two conflicting views of the world (1) have provided the overall frameworks for thought in western culture. The present paper shows neither view is sufficient for human understanding of many important systems and behaviors. A third view which appears sufficient is presented. Illustrations of the third view show increased understanding is obtained in many problems.

The sufficiency of the historic views and the route to the third view are provided through discussion of the issue of multi-disciplinarity, the question of whether it is possible to base everything we know on one discipline, or, on the contrary, if there is a logical necessity for using principles and concepts from many disciplines to achieve human understanding of the world.

The present article provides three distinct proofs of the logical necessity of multi-disciplinarity. The proofs proceed via study of: (1) the hierarchical structure of proto-typical systems in various areas of human concern; (2) the use of "integrated-control-information" by life forms and human artifacts; and (3) an extension of the theory of dimensions. The three proofs interlock, confirm, and extend each other.

Introduction: Three Views of the World

Since the time of Galileo, there have been two primary, but conflicting, overall views of the world in western culture. Each proclaims priority as a universal method. Each is, in a sense, "one-way." Each intimates (or in some versions declares) that human life is predetermined by non-human forces.

In this article, I will offer three arguments each demonstrating that neither of the existing views is sufficient for human understanding of five of the six major classes of systems of central concern to humans (owing to the inherent hierarchical structure of these systems and to the way information is utilized in controlling the structures). These proofs indicate the need for multi-disciplinarity and suggest a third view which takes into account the hierarchical structure of systems and the way control information is used. Illustrations are given which show this third view leads to improved understanding and to research agenda for resolution of ancient, unresolved issues. The third view also provides a framework that moves toward resolution of the older views.

The first view is ancient; it exists as far back as we have traced the ideas of humans. It is embodied to a significant degree in nearly all religions and ancient mythologies. It is "top-down" and states in essence that there are "higher powers" that govern and determine the actions in all the lower layers of structure in the world. I will call this "the holistic view." (The word "holist" must not be confused with the term "holism." Holism is the emergence of new BEHAVIOR exhibited in the higher levels of aggregated systems. The word holist is used here to denote a VIEWPOINT.)

---

(1) The word "world" in this paper will denote the earth and what humans know of the rest of the universe.

40

The second view is "modern," roughly 300 years old. It is the prevailing view of most "science." Explicit formulation of this view is usually attributed to Galileo, who remarked, "*Ultimately we must understand everything in terms of the motions of matter.*" The view has been echoed by many notable scientists, particularly firmly by Laplace. It appears to be the dominant view held by current physical and biological scientists. I will call this "the reductionist view."

The reductionist view is essentially a "bottom-up" view. In its extreme form it makes two claims: (i) all material objects are made up of "particles" of matter; (ii) one can therefore aggregate particles (by integration) and thereby find (or derive) ALL THE BEHAVIOR OF ALL SYSTEMS. The caveat is often added to claim (ii) that this can be done "in principle," but has not been carried out because of "practical difficulties." The work of carrying out these two claims will be called the "Reductionist Program." Since the views of what constitutes elementary "particles" (or waves) have shifted over time, for this discussion we will use the term "particles" to imply the best available current description in physics of the lowest known level of matter so that the reductionist view in this discussion can include either a classical or a quantum description of matter.

There appear to be few, if any, reasons to doubt claim (i). I will therefore take claim (i) as correct for the present discussion. However, claim (ii) is false, and I will give three proofs any one of which is sufficient to establish the falsity. More specifically, I will enumerate six major classes of systems covering all (or nearly all) areas of human concern, and show claim (ii) is impossible to achieve in five of these six classes of systems.

To avoid misunderstanding, let me reiterate: the claims (i) and (ii) stated two paragraphs above are an extreme form of statement; there are many less global versions of the reductionist view. Various reductionist views based on biology have recently been given with differing degrees of firmness. In its most extreme form this biological reductionist view seems to imply that the structure of DNA (that is genetic inheritance) governs and determines human life and human purposes; however, the precise claims are not made clear in many of these statements. One task of this paper will be to examine what can and what cannot be done by using the reductionist view more accurately than has been done in the past, thereby enabling us to use the great power of reductionist view, but also to see its limits so that we will know when it must be augmented by additional observations.

Also to avoid misunderstanding, let me note that I have no wish to deny the power and utility of the methods of science WITHIN THEIR PROPER DOMAIN. These methods have proven in the past three centuries so powerful in examining and coming to understand the structure of ourselves and our world, that it would be hard to overestimate either their theoretical or practical importance. They have revolutionized the human world. They are a necessary part of the knowledge needed to create our ability to fly through the air, live under water, communicate with each other in real time around the world, build bombs powerful enough to destroy the planet, and the other wonders of modern sociotechnical systems we all know. The power created by these systems have made us the effective rulers of the planet. The most urgent questions that confront us in the 20th century concern how we will use those powers--for good or for evil. Thus the reductionist method has not lacked success; it is rather that we have overstretched it. We have assumed it will do things it cannot. It is a matter of success overrunning itself. We need to be clearer on the limits of the reductionist program; that is a central topic of this paper.

The third view appears new, but like many new ideas it has precursors and has been used before in special cases. Bohr, for example, used the central idea of the third view in the creation of quantum mechanics in what he called the principle of correspondence. The Stanford engineer, W.C. Reynolds, used it in a leading undergraduate text in thermodynamics. Some current thinkers (for example R. Russell at Berkeley GTU, Roy [1979]) are using it in efforts to reconcile religion and science. However, this third view does not seem to have been generalized or formalized, nor have its consequences been examined systematically in any work I have been able to find to date. I will call this third view "Consistent." I will explain and define the consistent view following the proofs that the two older views are insufficient, because those demonstrations will lay the groundwork and point the way toward the consistent view.

Precis of the Demonstrations

Since the demonstrations involve several steps and some unfamiliar concepts, a precis of these steps is provided. The steps are:

A. Show by examples from many types of systems that most of the systems of the world (and universe as far as we know it) have hierarchical structure;

B. Provide a global picture (in the form of a hierarchy of constitution) and locate the disciplines of knoweldge on this hierarchy;

C. Demonstrate that the hierarchical structures of organisms, ecologies, machinery, human-created systems, communications, human interactions, and values systems typically have three characteristics. They:

- Incorporate "Dual-level-control interfaces" (as noted by Polanyi [1968]);
- Utilize "integrated-control-information" in feedback functions;
- Have differing (exogeneous) variables and dimensions at different levels in the typical structures.

The word exogeneous is unfamiliar in many disciplines, but is precise for our purposes; it denotes literally "out of the class of." The two phrases "dual-level-control" and "integrated-control-information" are central concepts we must have. I name them here to highlight their centrality. I will provide explanations in context.

Each of these three characteristics will be described in order to demonstrate that each, by itself, prohibits the completion of any form of the reductionist program even "in principle" for the TOTALITY of systems of human concern. Since the number of important examples for each characteristic is very large, and also because we need a logic that "closes," we will proceed in each case by the method of "negative inference" (2). In this method one uses counter-examples to falsify hypotheses thereby narowing the possible domain of truth assertions. Logically, one counter-example is sufficient to destroy a hypothesis. However, I will typically give two or three to make the proofs robust.

D. Generalize the Proofs. Generalization of the proofs is given by erecting a taxonomy of six major classes of systems covering all (or nearly all) areas of human concern, and indicating the situation for each class regarding the possibility of completing the reductionist program.

E. State the Consistent View. A new view called "Consistent" will be erected and summarized in a "Principle of Consistency." This view is mandated by the logic for most classes of systems of human concern; the major exception is noted.

F. Provide Operational Procedures for the Consistent View. An Operational procedure suggested by the Principle of Consistency is stated. A few examples are given. Implications for STS and S-STS studies are discussed to the extent allowed by available space.

---

(2) For a good discussion of this method, see Platt [1966]; he uses the title "strong inference," I prefer negative inference.

A. Examples of Hierarchy as a Structural Feature (3)

Hierarchy as a structural feature characterizes most parts of the world we know. There are two major forms of hierarchical structure: trees and ladders. Sometimes we find mixtures of the two forms. Illustrations of tree and ladder hierarchies, and one mixed hierarchy, follow.

Hierarchy of Human Speech (Tree Structure)

5 Message
4   Style
3   Grammar
2   Words
1   Noises

In this hierarchy of human speech, I have put arbitrary numbers at the left and also indented to indicate the 5 levels (or layers) of the structure. In the examples of tree-structured hierarchies which follow, I will only indent to indicate layers and omit the numbers.

In the hierarchy of speech notice that each layer has fewer elements than the next lower level; hence the name "tree structure."

Hierarchy of Human Structure (Tree Structure)

Complete Human Organism
- Major "systems" of organism
  - o brain (control level; has internal hierarchical structure)
  - o cardiovascular,
  - o neuromuscular,
  - o digestive,
  - o . . . .
  - Cells
    - Macro-molecules
      - Atoms
        - Subatomic particles

In this hierarchy of human structure, and in other examples that follow, sub-elements of a given layer will sometimes be listed following circles, for example, the brain, cardiovascular, ec., under major systems. Four dots are used to indicate when the list of sub-elements is incomplete. The first letter naming a level is capitalized, sub-elements illustrating a level are all lower case.

The use of the word "Tree" as a form of hierarchy reminds us that plants also have hierarchical structure. Essentially all living organisms have hierarchical structure. What we call "complex" organisms, such as mammals, have more layers of hierarchical structure than simpler organisms.

---

(3) Hierarchy has a bad name with many people. We tend to associate it with the oppressive features of Roman legions, rigid bureaucracies, and autocratic power. However, hierarchical structure is nearly ubiquitous in the world. We must have the concept if we are to form a good model of the structures of our world. Therefore, in this paper, hierarchy will denote only a structural feature, not its social uses.

Hierarchy of a Mountain (Tree Structure)

- Mountain
  - Strata (or rock layers)
    - Rocks
      - Molecules and atoms
        - Subatomic particles

Continents, oceans, the atmosphere, . . . also have similar hierarchical structure.

Hierarchy of Undergraduate Students (Ladder Structure)

Senior
Junior
Sophomore
First-year Student

Ladders have the same (or nearly the same) number of elements at each level, and often therefore describe human cohorts that move through time such as babies, children, parents, grandparents, and so on. Ladder hierarchies are shown without indentation of the levels.

Hierarchy of Human Needs (Maslow Ladder)

Self-fulfillment of potential
Self-Esteem
Belongingness (love and affection, community)
Security (economic needs)
Survival (physiological needs)

There are many lists of human needs; the Maslow ladder is a widely used one. The levels in the Maslow ladder indicate the priority in which individual needs are typically fulfilled. The priorities are even stronger for a society because of the effects of averaging.

Hierarchy of a Machine (Automobile; Tree Structure)

- Automobile
  - Main assemblies
    - frame
    - chassis
    - engine and power train
    - . . . .
      - Sub-assemblies (engine illustrated)
        - carburetor
        - distributor
        - . . . .
          - Parts (distributor illustrated)
            - rotor
            - cam
            - . . . .
              - Molecules and Atoms
                - Subatomic Particles

For our purposes, the Automobile is a good example of an artifact, a human-made object. It is generally known, complex enough to illustrate most structure features, and has important social implications. The structures of airplanes, TV's, washing machines, artillery, computers . . . are also hierarchical.

A Hierarchy of Concepts (Mixed Tree-Ladder Structure)

Concepts for building "rules"
Rules for deciding validity of "Principles" (Theory of choice)
Principles Predicting Behavior in Class of Concern
    Taxonomy of observations, concepts, and/or items
        Observations

This mixed tree-ladder hierarchy of concepts shows tree relations indented and ladder relations aligned vertically. I show this particular hierarchy because it not only indicates the need for hierarchy in concepts but also shows that the notion of two layers in theory building (observations and principles) is too simple. The necessity of hierarchy in both concepts and communications is wel known. It is formalized in Russell's Antinomy. Many other reasons are given by Watzlavick et al. [1967].

These examples do not nearly exhaust the list of hierarchical structures in the world, but they are enough to make the point we need. We have seen that the typical structure of naturally occurring inert objects, organisms and artifacts are hierarchical, and these are all the kinds of material, corporeal, objects in our world. We have also seen that communications, human needs and concepts typically have hierarchical structure; indeed, all three often demand use of hierarchy to avoid confusions or paradox. Values often have hierarchical structure, but in this case the structures are typically more flexible from one individual to another and less easily given general form. The Linnean "tree-chart" that organizes biology is a tree hierarchy. Many other taxonomies showing hierarchical structure exist, for example, organization charts of institutions. We need not go on. We see that hierarchy is indeed nearly ubiquitous as a structural form in our world. You can check this fact for yourself by considering other examples.

Our next step will be to illustrate a "top-level" hierarchy. We need this top-level view not only to provide an understandable picture of the location of the major systems, but also because the location of the disciplines of knowledge will be important. I call this "top-level" hierarchy of structure the "hierarchy of constitution." It is shown in Fig. 1.

B. An Overall Hierarchy: The Hierarchy of Constitution

The hierarchy of constitution is based primarily on physical size. The hierarchy of constitution shows the three major types of corporeal objects [inert naturally occurring, artifactual (human-made), and biological] in separate columns for clarity. Notice that the layers of most concern to humans are in the middle level of sizes. The number shown for the layers are merely for reference and are wholly arbitrary.

The number of levels in the hierachy of constitution is finite. There are roughly a dozen layers not counting the unknown layers at the bottom and the top. Since all taxonomies are arbitrary, human-built models, one can make some changes in the layers, but most of the interfaces that delineate layers are quite clear and unambiguous. For example, we have no great difficulty in distinguishing molecules from rocks, nor planets from solar systems, and so on; these distinctions are natural and clear; they are part of reality as we now know it.

Figure 2 shows the location of some disciplines of knowledge in terms of the layers of the hierarchy of constitution from which they grow and to which they relate. The level numbers are the same as in Fig. 1. Owing to the space limitations of a page, not all disciplines are shown. However, anyone familiar with a discipline can readily place it on Fig. 2.

Notice the clustering of disciplines in the middle level. This is not surprising since these are the levels of primary human concern. The far-away levels are of interest to us

FIGURE 1
THE HIERARCHY OF CONSTITUTION--A GLOBAL PICTURE
-*-*-*-*-

LEVEL OF SIZE	BIOLOGICAL FORMS	HUMAN-MADE OBJECTS	NATURAL PHYSICAL OBJECTS
9	///		UNKNOWN
8	///		UNIVERSE
7	///		GALAXIES
6	///		SOLAR SYSTEMS
5			STARS, PLANETS...
4	GLOBAL ECOLOGIES	SOCIOTECHNICAL SYSTEMS OF TRANSPORT	CONTINENTS, OCEANS
3	LOCAL ECOLOGIES	SOCIOTECHNICAL SYSTEMS -HUMAN MADE ECOLOGIES	GEOLOGIC FEATURES MOUNTAINS, VALLEYS...
2		LARGE HARDWARE	
1	FAMILIES, COLONIES	HARDWARE (ARTIFACTS)	
0	MULTICELLULAR PLANTS, ANIMALS	MATERIALS (STEEL, SEMICONDUCTORS...)	AGGREGATIONS OF ATOMS AND MOLECULES
-1	UNI-CELLULAR PLANTS, ANIMALS		
-2	ORGANELLES, MACRO-MOLECULES		INDIVIDUAL MOLECULES
-3	///		INDIVIDUAL ATOMS
-4	///		SUBATOMIC PARTICLES
-5	///		UNKNOWN

primarily to the extent that they affect the middle levels. However, the absence of any single integrating discipline for the complete set of systems in these middle levels is surprising and suggests a deficiency in our current scholarly arrangements. This deficiency has led to a failure to grasp the most important meanings of the word "technology"; see Kline [1977,1985].

Notice also that mere size does not indicate the complexity of the major features of the system; the most complex systems lie in the midle range of size on Fig. 1. This will be important for understanding later results in this paper.

C. Three Characteristics of Hierarchical Structures

1. Interfaces of Dual-level Control: Proof One

The concept of dual-level control is the work of Michael Polanyi [1968]. I will utilize Polanyi's ideas with the two other demonstrations that follow to enlarge the range and clarify the import of the results. The concept of dual-level control is probably best understood in terms of examples; I will use three in this section: human speech, an automobile, and a human being.

FIGURE 2
LOCATION OF SOME DISCIPLINES ON THE HIERARCHY OF CONSTITUTION
-•-•-•-

SIZE AS IN FIG 1	REPRESENATIVE OBJECTS FROM FIG 1	SOME RELATED DISCIPLINES OF KNOWLEDGE
9	UNKNOWN	//
8	UNIVERSE	ASTROPHYSICS
7	GALAXIES	ASTRONOMY
6	SOLAR SYSTEMS	ASTRONOMY
5	STARS, PLANETS...	ASTRONOMY, ASTRONAUTICS
4	CONTINENTS, OCEANS	OCEANOGRAPHY, METEROLOGY, GEOLOGY, INTERNATIONAL RELNS, STS
3	GEOLOGIC FEATURES MOUNTAINS, VALLEYS.. LARGE STS INCLUDING HUMAN-MADE ECOLOGIES	GEOLOGY, ECOLOGY, NAVIGATION, SEAMANSHIP, AERONAUTICS, FORESTRY, MARINE BIOLOGY, AGRICULTURE, ECONOMICS, POLITICAL SCIENCE, GRAD BUS, PUBLIC HEALTH, URBAN STUDIES, LAW, ENGR ECON SYSTS, OPERS RES, HISTORY, STS GEOGRAPHY, FOOD RESEARCH, PUBLIC POLICY ...
2	COMPLEX HARDWARE GROUPS OF PEOPLE	CIVIL ENGRG, ELEC. ENGRG, MECH. ENGRG.,.... MEDICINE, EDUCATION, LIBRARY STUDIES, COMPUTER SCIENCE, ...
1	FAMILIES, COLONIES HARDWARE	PSYCHOLOGY, ETHNOLOGY, FEMINIST STUDIES, PALEO-ANTHROPOLOGY, ...
0	MULTICELLULAR PLANTS & ANIMALS	ZOOLOGY, BOTANY, ANATOMY, PSYCHOLOGY, BIOLOGY, LANGUAGES, LINGUISTICS, HUMANITIES, ARTS, ENGLISH, MATH, STATISTICS MEDICINE (MANY BRANCHES),....
-1	ONE CELL ANIMALS	PARASITOLOGY, BIOLOGY
-2	INDIVIDUAL MOLECULES	MATERIALS SCIENCE, CHEMISTRY
-3	INDIVIDUAL ATOMS	ATOMIC PHYSICS
-4	SUBATOMIC PARTICLES	SUBATOMIC PHYSICS
-5	UNKNOWN	//

To begin, look back at the hierarchy of human speech given above, and think about the lowest two layers, those of noises and words. What can we say about human-made "noises" and "words" and about the relationship between them as used in speech? Examination of how these layers interact in speech leads to four facts.

a. The principles of acoustics and the physiology of the human vocal apparatus limit the list of (that is, CONSTRAIN) the noises we can make in volume and form.

> Comments: (i) We cannot make words out of noises we cannot utter. (ii) A sufficient list of "primary dimensions" for describing sound is: mass, length, time, and temperature. All the terms in the equations of acoustics, and therefore in the solution also, can be compounded solely from these four primary dimensions.

b. Not all the noises we can utter constitute words in a given language; there always remain utterable noises that are not words in a particular language. Noises are words, in a given language, by virtue of social consensus. The consensus may be informal, peculiar to a discipline or subculture, or generally accepted via a dictionary standard. Thus the vocabulary of the language constrains the list of noises that are words in a given language.

> Comments: (i) The dimensions of words are "symbolic forms," meanings if you like. Nouns represent classes of objects, verbs classes of actions, adjectives qualities, and so on. (ii) Few matters are more completely determined by social consensus than words.

c. The noises we can utter do not DETERMINE the words of a language; they only constrain the list of possibilities.

The proof of this assertion is simple; there are something like 2000 human languages on earth, all constructed from 'utterable' noises. It follows that we cannot derive a vocabulary from acoustics and/or the physiology of the human vocal apparatus.

d. We cannot derive the principles of acoustics from a vocabulary. Thus a vocabulary does not determine the rules of acoustics.

The proof follows from the fact that the dimensions of a vocabulary do not include any of mass, length, time, and temperature. Nor does anything in a vocabulary hint at the nature of wave propagation in air which is the essence of the sounds of speech as a physical phenomenon. There is no way to erect the principles, or the equations of acoustics from a vocabulary alone. Our ancestors understood and used language long before there was written history, but it is only after there is clear understanding of elementary mechanics, elementary thermodynamics and detailed knowledge of the carrying medium (air), that we were able to create what we now call acoustics.

These four facts taken together define the relationship of the TWO ADJACENT LEVELS of noises and words as used in human speech, the adjacent layers constrain but do not determine each other. Moreover, the relationship generalizes. It is set off for emphasis:

> IN A HIERARCHICAL SYSTEM WITH DUAL-LEVEL-CONTROL INTERFACES, ADJACENT LEVELS CONSTRAIN BUT DO NOT DETERMINE EACH OTHER.

The preceding sentence, in CAPS, is the general structural relation between adjacent layers of an interface of dual-level-control as Polanyi noted; indeed the apt phrase dual-level-control is Polanyi's.

It is vital that the nature of this relationship be clearly grasped, and this demands clear understanding of the distinction between the concept of CONSTRAINT on the one hand and DETERMINATION on the other. I therefore provide an illustration.

Consider the location of the dog in a fenced backyard. The fences CONSTRAIN the motion of the dog (presuming s/he cannot get over, through or under them). But the fences do not determine the dog's location completely. If it is a big backyard, the dog can move over considerable distances; if it is small, the dog's possible locations are more limited. Thus constraints limit the range of variation, tightly or loosely, or limit the items in a list (such as vocabulary). Constraints set bounds, but leave room for some variation. In the case of the dog, if we tied all four feet tightly to stakes in the ground, then the dog's location would be fully constrained, that is, DETERMINED; no degrees of freedom for motion would remain.

Given this understanding, we see that we cannot integrate over the principles of acoustics (even with full knowledge of the human vocal apparatus) and get words. Acoustics plus the relevant physiology do not determine words; they only constrain the list. Moreover, the existence of 2000 languages tells immediately that the constraint is not tight. This much Polanyi noted; in fact he used this example. But he did not say we cannot differentiate speech and find the rules of acoustics or physiology, and that is also true for the same reason. The vocabulary of a language constrains the list of noises that are words, but does not determine the full range of possible noises. One can say "GLUBBIBFOOBANG," but it is not a word in English (or any other language I know). For our purposes, we need to recognize that neither the integration from a lower layer, or a differentiation from an upper layer can obtain ALL of the properties of the adjacent layer across an interface of dual-level-control.

Polanyi also noted that the other three interfaces in the hierarchy of speech, those of words/grammar; grammar/style; and style/meaning are also all interfaces of dual-level-control. You may want to check this for yourself.

Next we will consider the example of an automobile. However, we will imbed the hierarchical structural of the automobile shown above into a more complete hierarchy representing a system of transportation.

A Hierarchy of Automobile Transportation (Control elements indicated in parentheses)

Social System (Social Control)
- o traffice Laws of the State
- o rules of the Road
    - Driver (Open Loop Control, including driver)
    - Comment: Some characteristics felt by the driver include: road feel; cornering, ...
        - Automobile (autonomic controls)
            - Major Assemblies (Steering, engine, ...)
                - Component parts, and lower levels

Imagine yourself driving an automobile. You hold the steering wheel, and have your feet on the accelerator and/or brake pedals. A truck suddenly looms in front of you. You turn and/or brake to avoid the truck. You control the car. It does not control you. You are in the central operating control loop. You sense what is happening, and take appropriate actions to control the car. This is a feedback loop, a set of actions in which you acquire information, process it, and act on the processed information. If you are an experienced driver, you do not stop to think about what to do; you combine the signal with prior knowledge and act on this COMBINATION. If you have to take time to think, the delay makes it much more likely that you will hit the truck. Possession and use of integrated-conrol-information characterizes the expert in any area as discussed in detail by Dreyfus and Dreyfus [1986].

Are you entirely free from constraints while avoiding the truck? Certainly not! If you corner too fast, you will roll over. You can only decelerate as fast as the condition of your brakes, tires and the road permit. As the car slows, autonomic controls in the engine adjust the amount of fuel going to the cylinders, the spark timing (and other functions) automatically, through closed feedback loops designed into the engine. In an open loop, a human being takes in the information, processes it with prior knoweldge and/or neuromuscular patterns and reaches "integrated-control-information" as a basis for action. In a closed or autonomic loop, the feedback pattern is built into the human-designed, and human-built artifact (in this case, the engine).

There are also constraints that arise from higher levels, the social control: the laws of the state, and the rules of the road. These are more flexible; you may, for example, alter the way you control the care depending on whether there is a police car in view. They are nevertheless constraints; they are the only thing that keeps the cars coming at you on their own side of the double line.

As in the case of human speech, the various levels in the automobile structure and also in the higher levels of car/driver/social-system have interfaces of dual-level control. Each lower level, L, constrains but does not determine the upper layer just above it, U. Conversely, each upper level U constrains but does not fully determine the next lower level L. But there is a difference we need to note between the action of U on L, and L on U. This concerns the levels of control.

The upper level U, of an interface of dual-level-control, "harnesses" the lower level and makes it do things the lower level, out of the context of the given hierarchical structure, would not do. This is the typical control relation in hierarchical systems with dual-level control interfaces. It is also set-off in capital letters for emphasis:

> THE UPPER LAYERS HARNESS THE LOWER LAYERS AND MAKE THEM DO TASKS THE LOWER LEVELS, OUTSIDE A HIERARCHICAL STRUCTURE OF DUAL-LEVEL CONTROL, WOULD NOT DO.

The two statements in caps, one on control relations and the other on structure, for hierarchical systems with interfaces of dual-level control are of sufficient importance in the world that it will be useful to have a name for them. I suggest we call the two together "Polanyi's Principle."

Does this mean a system with dual-level-control interfaces violates the governing principles of physics or biology at the lower layers? Of course not! If the upper control levels tried to make the lower layers violate these principles, the task would not get done. The system would not go, would die, would explode, or would fold, spindle or mutilate itself in some other way.

If you look again at the situation in human speech, you will see this control relation holds for the four interfaces in that case also. The same is true more generally for living organisms. Space does not permit exploration of the numerous important examples of living systems which embody interfaces of dual-level-control. Hence, I will discuss only the general features, and you can test examples for yourself if you desire.

Living organisms harness the lower levels of functioning in order to carry out life functions. As one writer puts it, animals carry out in this way the four "F's" of survival of the species: feeding, fighting, fleeing and reproducing. Plants only do two of the four "F's," feeding and reproducing, but they also typically use hierarchical structure with dual-level control. By use of hierarchical structures with interfaces of dual-level-control, living systems utilize available energy in the combination of food, water and air in order to function. During growth or repair of parts, living systems use this available energy to CREATE ORDER. These actions in normal functioning and in growth and evolution in no way violate the "laws" of thermodynamics when those laws are expressed in the proper frame of reference--despite much speculation for many decades based on inappropriate formulations for living systems (details can be supplied on request).

We humans also do other things beyond the four F's. For example, we make automobiles in sociotechnical systems of manufacture and diffuse them into sociotechnical systems of use (transportation systems) in order to move ourselves and other things about more rapidly and effectively. We make perfumes to titillate our erotic senses. We make atomic bombs and mount them on missiles in order to kill other humans, and thereby risk destruction of the planet. And these three examples are only a few of many. Almost without exception, these artifacts, and the systems in which we imbed them, are hierarchical structures utilizing dual-level-control interfaces. They are not simply aggregations of molecules that bump into each other in random ways. If you doubt this, it will help to remember that a modern automobile has about 10,000 parts, and each part needs on the average, say, 10 instructions for its manufacture. Thus roughly 100,000 parameters must be set, appropriately, before the drawings are sent to production by the engineers if the car is to operate successfully. How long would we have to wait for the bumping together of molecules to design the next model of a Chevrolet or a Toyota well enough so it would run? Cars are created by a human design of a hierarchical structure containing interfaces of dual-level-control in order to harness the molecules to perform desired human tasks, tasks that the molecules left to themselves would not do. Human purposes (of some sort) are "built-in."

Applying these examples to the central question, we see what prevents success of the reductionist program is not mere system size. The reductionist program can succeed for a NATURALLY OCCURRING system that is enormous but HOMOGENEOUS in aggregation. A very large collection of gas, such as the earth's atmosphere, and a very large crystalline solid are good examples of such systems. What makes the reductionist program impossible in other classes of systems is HETEROGENEOUS AGGREGATION, that is, COMPLEX ORGANIZATION OF THE SYSTEM IN HIERARCHICAL LAYERS, AND/OR THE CONSTRUCTION OF THE SYSTEM FOR HUMAN PURPOSES.

In most human artifactual systems and in living systems (organisms), we cannot find all the properties of an Upper level U of the system by integating over the next lower level L, because the layers constrain but do not determine each other. Polanyi noted this explicitly in 1968, for some types of systems, but the article does not seem to be very widely known. We also see that we cannot find the complete behavior of a lower level L from an upper level for the same reasons--the layers constrain, but do not determine each other. Since all living systems and nearly all artifactual systems have such structure, the inability to determine behavior by integration or differentiation from adjacent layers cannot be ignored for such systems.

To make this more specific, you might ask yourself the question, "Can we find the driving qualities of an automobile from integration over the lower levels of, say, the molecules, or its main assemblies?" The answer is quite clearly, "No!" Driving qualities such as roadability and cornering depend on human preferences, not molecular actions or the kinematic motions of the assemblies in the car. Human preferences enter; some people like a 'hard' ride with sharp cornering; others prefer a 'soft' ride. We only learn what is desired from human responses; only after we learn that can we codify some of the results into design criteria for the assemblies. In Detroit there is a saying that such characteristics are finally determined only by the "ASSID TEST." That test occurs when the President of the Company joins himself with the driver's seat and tries out the car. In doing this, the president draws on long experience in driving and assessing cars; he uses information outside the domain reachable by analyzing parts of the car. This leads naturally to the second proof.

2. The Use of Integrated-Control-Information: Proof Two

The existence and use of integrated-control-information by living systems (and more and more commonly by human artifacts and artifactual systems) constitutes a second reason why the reductionist program cannot be carried out for many major classes of systems even "in principle." What does the phrase "integrated-control-information" denote?

As we saw in the example of the automobile and driver in the preceding section, hierarchical systems often have distinct levels of control. In reacting to the sudden appearance of the truck in front of you, you would go through several steps: You would acquire information (Oops! Truck in the way); You would integrate this information with your stored experiences in the brain and the neuromuscular system; and you would act using your muscles (Slam on the brakes! Turn!) to cause the car to change speed and/or direction. To generalize this sequence the steps are: acquire information; integrate with prior information; take (corrective) action.

In the phrase integrated-control-information, the modifer "control" reminds us that the information is used in a control feedback loop. The modifer "integrated" reminds us of two things. (i) Information acquired via sensing; (ii) the acquired information is integrated with PRE-EXISTING INFORMATION AND PATTERNS IN THE SYSTEM. It is the combination of the pre-existing and new information, when put together into a new synthesis, that is the basis for action. Neither the new information nor the pre-existing information ALONE is sufficient to deal with the sudden appearance of the truck in front of you on the road. Nor does either the prior experience or the structure of the new car alone provide the information given by the ASSID test.

The existence of integrated-control-information, and its use in feedback loops in the control levels of hierarchical systems forms a second reason why the reductionist program is impossible in many important classes of systems. Integrated-control-information is not accessible via integration over the lower levels L of living systems. We will use humans to illustrate because we have some relevant characteristics which other organisms do not.

In humans there are three types of pre-existing information that are used to process acquired information and close various feedback loops. These are: (i) DNA (genetic information); (ii) the cultural information of the "tribe" or society; and (iii) individual information acquired by experience and stored in the brain and/or neuromuscular system. All three of these types of information COME FROM THE PAST, THEY PRE-EXIST. None of these types of information can be found by integrating over lower levels in present time. They come out of the past, and they involve quantities (information) not determined by the lower levels.

If the lower levels fully determined (rather than merely constrained), the spatial arrangements of DNA would lead to only one species on earth; a recent estimate by Wilson [1985] suggests there are tens of millions. Nor do the lower levels in the hierarchical structure of our bodies determine cultural forms. In the 20th century anthropologists have documented the existence of about 2000 "tribes" on earth. The variations in cultural forms among these tribes are so great that they were literally unimaginable before the cultural anthropologists began to study and record them. Similarly, each of us has a unique experience, and therefore has a unique information patterning in our brain and neuro-muscular system, and without this integrated-control-information we could not avoid the truck on the highway, nor could we walk, talk, or do much of anything in our daily lives. As documented by Konner [1983] the human child's early experiences strongly affect the number and form of the physical connections in the brain, and each of us has a unqiue set of these experiences. As many psychiatrists have noted, each person is different, a new problem with new emotional patterns to be learned and treated (e.g., Jung's autobiography, or Viscott [1972]).

There is not space in this article to fully explore this topic, but two more points need to be made. First, organisms and current human-made artifacts use many types of feedback loops for control functions. However, inert, naturally occurring objects (rocks, mountains, lakes, the air around us, ...) do not have feedback loops of any kind. Indeed, inert, naturally occurring objects have no capacity either to acquire or to process information. This is a fundamental difference between living and inert systems. Or to put it differently, if you can talk back to the doctor, you're alive! Second, we now routinely build some of this "life-like" quality into human-designed artifacts.

Thus we ought not to expect inert, naturally occurring systems (nor the principles describing their behavior) to encompass all the behavior of living systems, nor of our artifacts. They lack information and feedback functions vital to living systems. We must learn about those feedback functions by studying living systems. If the equations we write for inert, naturally occurring systems contained terms that described the acquisition or processing of information, they would be inappropriate for those systems; they would predict behaviors that such systems cannot carry out. Integration over the lower levels L will not find the critical feedback functions for us. This remark applies not only to integration over inert molecules, but also to integration over the information in DNA since that still does not determine either the cultural or the individual integrated-control-information, and both those are vital to actions we each take every day of our lives. To make this explicit, we need only recall that DNA does not FULLY guide the learning of a child. The human infant requires tender loving care (TLC) from adult humans; without TLC 100% of human infants die even when fed and sheltered. The connections developed in the brain of a human child are strongly influenced by the behaviors of the intimate caretakers during the first few years of life as Konner [1983] and many others have documented. Humans seem in these ways different from other animals. We are less developed at birth, and learn after birth matters that are already fixed in other species. The opportunities for this learning are built into our genes, but the explicit details of that learning are not. There is evidence of this fact on all sides if we choose to look. Study of the lower levels are vital for understanding how the functions operate, but such study will not give us ALL of the functions nor will they tell us the purposes of those functions.

I also need to rebut a possible rejoinder. A hard-line reductionist may ask, "Why can't we find the integrated-control-information by integrating over past time up to the present?" There are many reasons; I will give only two. To acquire the information in the DNA, information that has evolved over millions of years in humans and in other animals, would require obtaining information about the particular genes that were transmitted in every sexual act over all time and all the mutations that occurred in the processes of ovulation and gestation. That information no longer exists. We cannot obtain it, even if we wanted to grossly violate privacy by inserting the computer into the bedroom. Hence there is no way to initialize the program or carry through the steps. Second, if we try to avoid the first problem by beginning with creation and assuming (wrongly) that all further steps are determined for all time, and calculate the size of the computer required, we quickly find that the problem is literally "non-computable," in the terms defined by computer scientists. That is, for humans alone the problem requires more computer storage cells than there are known mass points in the universe; a computer large enough for the task cannot be built. This type of "non-computability" is not merely a condition of infeasibility; since no such computer can ever be built, it is a condition of impossibility.

In sum, the existence in living systems of integrated-control-information, coming in part from the past, makes impossible the completion of the reductionist program for at least many living systems. This is a second reason why the reductionist program is impossible in addition to the restrictions created by systems with dual-level-control interfaces.

It is worthwhile to note that the domain boundary where the ability to carry out the reductionist program ends in both the demonstrations given thus far is the point where information enters that cannot be obtained by integration from lower levels. This ought not to surprise us since molecules, left to themselves, cannot and do not gather, process or utilize information.

A metaphor that I find useful in thinking about the location of the boundary which limits the reductionist program is that of a statue. We have in hand a block of white marble. We intend to carve from it a statue. We can carve one of beauty, say a replica of Michelangelo's David, or one that most people would agree is ugly (choose your own example). The equations that govern the behavior of the "particles" in marble are the same for the ugly and the beautiful statues. It is the addition of human INFORMATION about shape not contained in the equations for the particles, human aesthetic preferences, that makes the difference. This is the case in most human-designed objects. It is the insertion of human purposes (aesthetic or other types) as information that forms an impassible barrier for the reductionist program.

The third demonstration of the impossibility of the reductionist program will indicate more clearly why such information cannot be obtained by integrating over the equations describing the behavior of "particles." The barrier arises from the inherent nature of physical theory itself.

3. The Theory of Dimensions: Proof Three

An independent proof of the theoretical impossibility of completing the reductionist program for many classes of systems can also be given from the theory of dimensions, as normally used in the physical sciences and engineering, when that theory is appropriately extended. What is the "Theory of Dimensions"? It is the theory of how the equations modelling physical reality are put together. I will recapitulate only a few salient points.

The theory of dimensions, as given for example by Bridgman [1921], and as extended by Kline [1965, 1986], shows that all the equations of the physical sciences, and all the solutions at the classical level can be written completely in terms of no more than six "primary dimensions." One such list is: mass (m), length (l), time (t), temperature (T), Voltage (V), and electric charge (C). The words "classical level" here denote objects of roughly human size. Since any integration over lower levels must come through this level to produce results of interest at that level or for larger objects in the hierarchy of constitution, the dimensions of lower levels need not be considered for this purpose; if they are different they must merge into no more than this list at the classical level. The list is sufficient, but neither unique nor always necessary. For example, we saw above that the first four were enough for acoustics. Also, we can easily substitute other sets of dimensions if we choose. However, a sufficient list is enough for our purposes.

Let us suppose we have a very accurate equation, E, an equation that is an excellent predictive model of the behaviors at a lower level L, and we integrate over that equation, in the sense of mathematics, to find results at an upper level U. Formally, we can write, in functional form:

$$E = f_1 (m^a, l^b, t^c, T^d, V^e, C^f)$$

In this equation, a, b, c, d, e, and f are real numbers. If we complete the problem by providing sufficient information about the particular case (boundary and/or initial conditions), and integrate, over time and space to "aggregate" the system at the upper level U, we obtain the integrated answer, I, in functional form as:

$$I = \int_{x_i} \int_{t_l} E dx_i \, dt = f_2(m^a, l^{b+3}, t^{c+1}, T^d, V^e, C^f); \;\; i = 1,2,3$$

Thus all that happens when we aggregate, and this is entirely general within the theory of dimensions and the operations of mathematics, is that we raise the power of the exponent of length by three and time by one. The important thing, for our purposes is that

NO NEW DIMENSIONS ARISE.

Now we ask, are these six dimensions sufficient to describe the behaviors of all systems in the world? Certainly not! Let me give a few counter examples. The primary dimensions of economics, in much the sense that primary dimensions are used in the physical sciences, are money and interest rate; the mathematical models of economics are built up using those primary dimensions. The primary dimensions of political actions are "followers" or "adherents"--regardless of how they are obtained and retained. The primary dimensions of communities of intimate others are love, affection, trust, and belongingness. (See Maslow Ladder above.) The primary units of value systems are beliefs and meanings. The primary dimension of integrated-control-information for humans is information (patterns and human purposes if you like). It is not just that one of these types of dimensions cannot be obtained by integrating over lower levels L, as various people have pointed out in qualitative arguments, it is rather that none of them can be obtained. Moreover, this is formally and easily shown from the theory of dimensions used in the physical sciences and engineering in the way given above. I have not seen an instance where the theory of dimensions has been extended that far in prior treatments. However, the extension is straightforward and appears appropriate. Nor have I exhausted the list of dimensions that cannot be obtained by integrating on equations that contain only m, l, t, T, V, and C as primary dimensions; however, one counter example is enough, and we already have more than half a dozen.

Finally, with regard to the theory of dimensions, it is important to note that it is not a trivial part of physical theory. The theory of dimensions is a precursor to writing any equations at all that describe inert, naturally occurring physical systems; it is an essential, necessary building stone on which both physical theory and engineering analysis rest.

D. Generalization of the Proofs

Up to this point, we have been proceeding by negative inference; we have been demonstrating properties of systems that make completion of the reductionist program impossible. We have given three separate but interlocking proofs, and in each case have mentioned several counter examples. Any one counter example for any system at all, which cannot be overthrown, is sufficient to destroy the claim of the reductionist program that one can, even "in principle," integrate over lower levels L, and obtain ALL BEHAVIORS of ALL SYSTEMS on upper levels U in hierarchical systems. We have now seen dozens of counter examples in a wide variety of systems. We have been at pains to show that one cannot differentiate in upper layer U and obtain all behavior in a lower level L in many systems either, since we want to be clear that the holist viewpoint is also inadequate for finding the detailed behaviors of systems that we humans need to understand our world.

Now we need to ask two questions. (i) "How widespread are the cases where we cannot find the complete behavior of upper layers U by integrating over lower levels L, nor lower levels L by differentiating over U?" (ii) "Are there any systems where we can find complete behaviors by integration or differentiation?"

Space does not permit a complete exploration, but I will indicate the answer, and you can check for yourself using the ideas of the three proofs given above the dual-level-control interfaces, about integrated-control-information, and/or about dimensions as suits your background and preferences.

Let us divide all the systems of human concern into six major classes with some subclasses as shown in Fig. 3. This taxonomy is arbitrary, but can be checked against the taxonomies of philosophy and the careful taxonomy of Phenix [1964]. The six classes of Fig. 3 will be seen to cover everything (or nearly everything), and that is all we need for this discussion.

Looking at Fig. 3, we see the examples given above demonstrate that we cannot carry out the reductionist program for any of the following: communication systems; living systems; artifactual systems; human systems; and values systems. Our counter-examples include several for each of these classes (if we take human preferences like auto-roadability to be values).

The only remaining class is systems of inert, naturally occurring objects, the domain of the physical sciences. There seems to be no theoretical bar for the reductionist program in the systems those disciplines study. It is then not surprising that physical scientists often have been or are reductionists. However, it is important that we not accept the reductionist view in any of the other five major classes of systems, for it will mislead us. It often has in the past, and still does in some instances.

Let me make this specific. Two important examples where use of concepts that are correct at lower levels were wrong when applied to upper levels of the past century are: (i) positivist philosophy, and (ii) social Darwinism. Both had important impacts for decades.

FIGURE 3

SIX MAJOR CLASSES OF
SYSTEMS OF HUMAN CONCERN

-+-+-+-

1. INERT, NATURALLY-OCCURRING:
   ROCKS, AIR, OCEANS, WEATHER
   ATOMS, MOLECULES, ...

2. ARTIFACTUAL:
   TOOL, MACHINES, STRUCTURES
   SYNTHETIC MATERIALS,
   SOCIOTECHNICAL SYSTEMS

3. BIOLOGICAL:
   ORGANISMS, ECOLOGIES

4. HUMAN SYSTEMS:
   SOCIAL, POLITICAL,
   ECONOMIC, AESTHETIC,
   AFFECTIONAL

5. VALUES

6. COMMUNICATIONS

Both are now known as notorious scholarly errors. Two important, still extant difficulties of the same sort are: (i) "Pavlovism," if one may call the simpler forms of behavioral psychology by that name; see, for example, Lynch [1985], and Beavers [1985]; (ii) difficulties in behavioral genetics documented by Gould [1986]. These examples do not exhaust the list of either past or current problems related to this souce. Over-extension of the reductionist idea into domains beyond the physical sciences have caused many important errors in the past, and are still vexing us. My own book, in progress, will document, describe, and classify this type of error in more detail.

E. The View of Consistency

If we accept the proofs given that the reductionist program is impossible to carry out in five of the six major classes of central concern to humans, what then do we do? We appear to have lost the three-century-old hope held out by science for achieving complete quantitative understanding of our world and the human condition.

Once we recognize that neither the reductionist view nor the holist view is sufficient, an answer is not hard to find. Indeed the proofs we have given point the way. If we cannot find the complete behavior of an upper layer U from lower layer(s) L, nor conversely, then we must augment what we find from levels above or below with direct observations on the system at all the relevant levels. This conclusion is central:

WE MUST MAKE OBSERVATIONS AT ALL THE
APPROPRIATE LEVELS IN THE STRUCTURE OF THE SYSTEM.

If we can find a given characteristic of a system from lower levels L (or higher levels U) and also by direct observation, then there is a logical demand that the two results be CONSISTENT, that the results be congruent. Two circumstances can then arise:

(i) If the results are consistent, there is no problem; we have merely cross-verified our answers. (ii) If the results found from two (or more) levels are not consistent, then we must seek the source of the error. Moreover, we must not argue that the lower level determines (or governs) the upper (or conversely) for any system in which there is hierarchical structure with dual-level control, or where the control levels for feedback functions contain integrated-control-information.

Thus far I have been able to identify five sources of possible errors that need to be checked when conflicts in results found from different hierarchical levels occur. These are: (i) error in principles or their application at level U; (ii) error in principles or their application at level L; (iii) error in the transformation processes carrying results from level L to U or conversely; (iv) double definitions of single terms; (v) assumption that the systems analyzed are the same when the are at least in part different at the two levels. There may be others. In cases where the principles are well established, we particularly need to seek the errors in the other three sources, and this often has not been done. This focus has already been productive in one case I will mention below.

The theory of dimensions provides us with still another piece of information. We cannot derive the complete results of one discipline from another, even when they lie at the same hierarchical level, if the primary dimensions of the two disciplines are exogenous to each other, even in part. For example, we should not expect the principles of economics to provide us with the complete behaviors for social systems nor political systems even though all three involve human groups and lie at the same hierarchical level of aggregation and size for at least some systems. Nevertheless, some forms of Marxist theory suggest that the complete social system is determined by the economic sphere. In another instance, some discussion of the appropriate steps in developing "less-developed" countries have suffered seriously from the expectations that the concepts and hence the dimensions of one discipline are sufficient to describe and hence to deal with the complete problem of "developing" a society.

These ideas are of sufficient importance that they seem to warrant embodying in a principle. This can be stated in many ways; one follows:

THE PRINCIPLE OF CONSISTENCY.

In systems with hierarchical structure, or in situations involving more than one field with some differing primary dimensions, COMPLETE SOLUTIONS MUST SATISFY THE PRINCIPLES IN ALL THE LEVELS AND/OR FIELDS.

Corollary: When solutions from more than one level in an hierarchical structure, or from more than one discipline of knowledge, provide results for a given behavior in the same system, then the results must be CONSISTENT, that is congruent where they overlap. If they are not consistent, then we must seek the source of error, and not argue that one layer or one discipline governs the other.

-+-+-+-

More specifically, we distinguish three cases:

Case (1) Systems with hierarchical structure and one or both of: (a) dual-level-control interfaces between layers; (b) use of integrated-control-information in feedback loops of control. In this case, we cannot derive the complete principles or behavior of an upper level U from lower levels L, nor conversely.

Case (2) There is more than one relevant discipline of knowledge, and some discipline (D) involves dimensions exogenous to the others. In this case, we cannot derive all of the behaviors or principles of discipline (D) from the other disciplines.

Case (3) There is a hierarchical structural in the system, but no interfaces of dual-level-control and no use of integrated-control-information in feedback loops. And, in addition, the same primary dimensions describe the behaviors at all levels. In this case, there is no known bar to derivation of behaviors and principles of upper levels U from lower levels L, nor conversely. However, this case occurs primarily in systems of inert, naturally occurring objects--the domain of the physical sciences. It is not typical of biological, human or artifactual systems nor of systems of concepts, communications or values.

F. Operational Procedures of the Consistent View

The previous section leaves us with two important questions.

(a) What do we do in the physical sciences themselves; is the reductionist or consistent view more useful in those fields?

(b) Does the principle of consistency provide us with useful operational procedures for tackling problems; is it practical?

I will answer (a) only briefly and tentatively since only limited experience now exists. Preliminary study of the question suggests that, ON BALANCE, it would be pragmatically far better to adopt the consistent view than the reductionist view in the physical sciences. There are a number of benefits: all the results obtainable in the reductionist view are still usable; we gain an added check; potential errors are highlighted, and their possible location focused; we gain clarity on the potential sources of errors in the relations between the levels in the hierarchy of constitution. On the deficit side, when we use the consistent view, we lose nothing I can see except a desire for apparent economy of principles, and a three-century-old dream of fulfilling Galileo's dictum that we must ultimately understand everything in terms of the motions of matter. Since that dream is impossible to fulfill in five of the six major classes of systems of human concern, we lose little by abandoning it in the sixth.

In my own work, I have followed this lead and applied the view of consistency to one problem in physical theory--the relationship between continuum thermodynamics and statistical mechanics. A focus on the questions given above has led to important clarifications in the understanding of the entropy principle and its implications for the world at large. I plan to publish these results separately sine they are too detailed and too technical for the present paper.

What about question (b): Does the viewpoint of consistency give useful operational procedures? The method of consistency, when taken together with the existence in many important classes of systems of hierarchical structure with dual-level control and integrated-control-information utilizing feedback loops to harness lower levels, suggests a very profitable set of questions. I will state one version of these questions, and provide two illustrations, one general and one specific.

The three essential questions one needs to ask about a system of hierarchical structure with dual-level control and integrated-control-information for feedback seem to be:

1. How many levels are there in the system structure?

2. How many degrees of freedom (things that can be altered independently) are there on each level?

3. Of these degrees of freedom, on each level, how many are constrained by the levels below and the levels above? And how many are left open for independent actions, thoughts, choices?

These three questions are minimum essentials for proper study of hierarchical systems, but are already sufficient to increase understanding in many ancient unresolved questions.

In many cases it is also important to ask a further set of related questions:

4. Which are the levels of control? Are controls open loop or closed, rigid or flexible? Can control be delegated, or is it fixed in a given level? These questions are only a "starter-set." Study of more examples is needed before they should be taken as an adequate basis.

Let me illustrate a general result of asking the three essential questions. We ask, "How does one find structure and values for a hierarchical system with dual-level control and integrated-control-information?" One looks at the lower levels of hierarchy WITHIN the system and also THE HIGHER LEVELS IN WHICH THE SYSTEM IS EMBEDDED. One finds structure by a downward loop from the level of the system, to as low a level as needed for the question in hand, AND return to the system level. One finds values by a loop, usually upward from the level where the system exists, TO THE LEVELS OF USE in the world.

For example, in the case of an automobile, one designs the car internally by looking at how the major assemblies fit into the total system, how the components and subcomponents fit into the assemblies and so on, and then returning to check overall functioning. If failure of parts is involved, or if one has on-board computer chips (as modern autos do), then this loop may need to be carried down to the level of molecules or lower in the hierarchy of constitution. This is the way actual designs are done, by going over the necessary loops, again and again, and again and again, until all the functions are satisfied at all the necessary levels, and this will usually include analysis, computation, testing, and over-the-road "assid" testing. This is, in fact, what is done despite decades of common wisdom that the process is "merely applied science" and that one can "in principle" carry out the design by a one-way process of integration over the lower layers. Any automotive engineer can attest to these facts, and the situation in general in the design of artifacts; it is not restricted to automobiles.

Where are the levels of use for an automobile? They lie at higher levels than the auto itself in the hierarchy of constitution. They occur in the transportation system, the social system of cities, and in the ecologies. Excessive focus on the lower levels by the industry in the past has conributed to the problems in these other areas resulting from the use of automobiles. The dominance of the reductionist view as the explicit method for science, and in recent years implicitly for engineering, has played a role in this overnarrow focus.

A moment's reflection ought to tell us that we do not want to understand and take into account structure OR values, that we need to understand and take into account structure AND values. Thus we need to use both the downward and the upward loops in the hierarchy of constitution as illustrated by the case of the automobile. This illustration is quite general. Structure is found by a downward loop to lower layers from the system of concern and return. Values are found by a loop to the levels of USE, usually upward to higher layers, and return. Neither the holist view nor the reductionist view suggests these two essential loops; each of those views suggests a one-way process: in one case top-down, and in the other "bottom-up." Thus they both fail to suggest critical processes we need to understand our world. The consistent view not only suggests but mandates these processes, and it suggests how to close the process: iterate, and keep iterating, until all necessary conditions are met on all relevant levels. The Japanese decision-making processes approximate the consisting view; Western processes usually have not.

To put this differently, the holist view does not show us how to find structure; it only gives us values. The reductionist view shows us how to find structure by looking in lower levels, but it does not suggest how to find values and hence fails to tie the information we achieve about structure to human purposes. The consistent view provides a frame inside which we can study and take into account both structure and values, and mandates that we do so.

For a specific application of the three essential questions above, let us turn to an ancient, unresolved and vexing question, "Do humans have free will, or is our life pre-determined by non-human forces?" This question has troubled philosophers for at least two millenia, and has not been answered. Let me suggest why. It is an "en-bloc" question about a hierarchical system, and as such has no answer. Another example may help us see the trouble clearly. Suppose we ask, "What is the temperature of an automobile?" We know that inside the cylinder the temperature may be 3000 F, in the cab it may be 70, and on the outside surface of the car it may be 40 below. There is no proper response because the question overconstrains the answer; there is no one temperature; the situation is different in the different parts and layers of the automobile system. That is also the case when we ask about free will as an "en-bloc" question. The classic formulation of the question emplies the situation is the same in all levels of the hierarchical structure, and the implication is untrue. Hierarchical structures with heterogeneous aggregation frequently (one might say typically) have different variables and different degrees of freedom in the different levels. Consequently, such "en-bloc" questions overconstrain the answer; they have no proper response. They generate non-answers that tend toward endless quarrels.

Let us ask instead the three essential questions suggested by the consistent view.

How many levels of structure exist in a human being?

Answer: Five physical and at least three levels of control in the brain. (We do not understand the brain well yet, but are rapidly learning more about its structure and functioning. Five levels of control is probably more accurate than three, and the situation is complicated in other ways. But let's take the lowest estimate, three, for discussion.)

How many degrees of freedom are there on each level?

Answer: So many we cannot count them on most levels. At least no one has given a good account. The human body has hundreds of degrees of freedom in mechanical motions alone. It has thousands of feedback loops according to some physicians I have asked. The brain has a hundred billion neurons and a thousand or so possible connections from each of these to other neurons. Moreover, the brain "minds" the body; we must be careful where the control levels lie.

How many of these degrees of freedom in a human being are constrained from lower levels by the laws of physics, chemistry and biology?

Answer: Only a handful are constrained by physics; a larger number are constrained by biology, but by no means all of them, either in the brain or in the muscle tissue. We saw this clearly in the variety of species, cultures and individuals and in the possibilities in driving and in designing of artifacts above.

The lack of total determination of brain and muscle is evident from numerous familiar things when we look about and do not merely try to synthesize from particles, or DNA molecules. For example, we create and alter cultures, languages, religions, artifacts, works of art and music using the integrated-control-information in the brain via open feedback loops. If all the degrees of freedom were determined, we could not do any of these things, nor could we avoid the truck looming in front of us. This merely begins the list of "open" (that is, free) functions.

Thus the questions suggested by the consistent view do not completely answer the question of free will. However, they do give part of the answer immediately: "Yes! There are some open degrees of freedom on some levels of the human structure; THE LOWER LAYERS ONLY CONSTRAIN AND DO NOT DETERMINE THESE LEVELS." Beyond the preliminary answer, the three essential questions "unpack" the problem of "free-will," and thus point the way toward a research agenda that can increase our knowledge of the answer over time. Perhaps even more important, this application of the consistent view illustrates how to stop trying to answer unanswerable questions and quarreling among ourselves about the various non-answers.

Is this result singular or is it typical? I cannot yet say for sure, but I can say that similar results have occurred in most of the other instances where I have thus far applied the three essential questions suggested by the view of consistency to hierarchical systems with dual-level-control interfaces and integrated-control-information. For example, if you ask the questions under item 4. above, "Where are the levels of control? Are they open loop, or closed loop? Which are rigid and which can be delegated?" And you apply these questions to the ancient mind/body duality, or to the ancient controversies over nature/nurture problems, or to the problems of delegation of authority in hierarchical institutions, I think you will see that here also the procedure begins to "unpack" the questions in ways that lead toward a useful research agenda and away from the endless, often bitter arguments that have characterized these issues in the past. These arguments too, seem at least in part the result of asking en-bloc questions about hierarchical structure which overconstrain the answers, thereby creating a situation where there is no proper response; only aguments over non-answers. It would be hard to find stronger support for the utility of the consistent view.

There is not space to provide more illustrations in this paper. You may therefore find it useful to consider some examples of personal interest from the consistent view to determine its scope and to see if it aids in thinking clearly. If you do so, I think you will find application of the consistent view to any problem in a professional field or of important scope in human affairs will seem familiar as a process. Once one has the idea, use of the consistent view becomes like the person who asked an English teacher to explain the meaning of the word "rhetoric," and on being told, exclaimed, "Why, I have been talking rhetoric all my life." Many of us have been using a consistent view for at least some problems for a long time because many problems demand it. However, we have lacked both a theoretical basis for doing so and specific questions to make the method operational. It is past time we gave up the oversimple holist and reductionist views in Western culture, and abandoned the three-century-old wrangle in which they have involved us. Both are inadequate in five of the six major classes of systems of human concern; that is a major reason why the wrangle has not closed. The consistent view is not only logically necessary, but also offers us a more cooperative way forward to increased understanding of ourselves and our world.

Conclusions

Study of the structure of hierarchical systems of a wide variety that occur in our world lead us to three interlocking proofs of the logical necessity for multi-disciplinarity. One proof is based on the existence of interfaces of dual-level-control, one on the existence of integrated-control-information in living systems, and one on a seemingly appropriate extension of the theory of dimensions as utilized in the physical sciences and engineering.

The results indicate that neither the ancient "top-down" holist view of most religions, or the "bottom-up" reductionist view that has characterized most science since its transition to the "modern" form in the hands of Galileo, are adequate procedures for finding the COMPLETE principles and behaviors of five of the six major clases of systems of human concern. The logic mandates instead a new view called consistent. In the consistent view, one does not claim that upper layers of hierarchical structure control and determine the lower layers, nor does one claim that the lower layers control and determine upper layers (since they only constrain and do not determine each other). One takes the view that the various layers have, to some extent independent characteristics and exogenous dimensions, and therefore that the principles and conditions must be satisfied on all levels and for all disciplines with exogenous dimensions that are relevant to the questions and the systems of concern. AND, if results from various layers provide differing answers for what appear to be the same situation, then one should seek the source of error and not claim one level governs another. Nor should one claim that one discipline governs another when the second discipline has, even in part, exogenous dimensions.

The questions raised by this new view, when coupled with the recognition of hierarchical structure utilizing dual-level control and integrated-control-information in feedback loops, lead to a view that allows us to study both values and structure instead of one or the other. It also "unpacks" many seemingly intractable questions and thus tends toward establishing research agenda that may provide more complete answers. The consistent view establishes a basis for multi-disciplinary work that is inherently more cooperative than the old claims of priority of one layer over another, claims that in any event are false for five of the six major classes of systems of human concern.

References

Beavers, W. Robert [1985], "Successful Marriage," W.W. Norton and Co. (See the comments on the six levels of potential sources of neuroses and compare with the older views.)
Bridgman, P.W. [1921], "Dimensional Analysis," Harvard University Press.
Dreyfus, Hubert, and Dreyfus, Stuart [1986], "Why Computers May Never Think Like People," Technology Review, Vol. 89, No. 1, pp. 42-61.
Gould, Stephen Jay [1986], "Evolutions and the Triumph of Homology, or Why History Matters," Scientific American, Vol. 74, Jan.-Feb., pp. 60-69.
Kline, S.J. [1965, 1986], "Similitude and Approximation Theory," 1965 McGraw-Hill Book Co. (being reprinted in 1986 by Springer-Verlag).
Kline, S.J. [1977], "Toward the Understanding of Technology in Society," 3 articles, Mechanical Engineering, March, April, May issues.
Kline, Stephen Jay [1985], "What is Technology?," Bulletin of Science, Technology and Society, Vol. 5, No. 3, pp. 215-8.
Konner, Mel [1983], "The Tangled Wing: Biological Constraints on the Human Spirit," Harper Colophon Books.
Lynch, James L [1985], "The Language of the Heart," Basic Books.
Phenix, Phillip H. [1964], "Realms of Meaning," McGraw-Hill.
Platt, John [1966], "The Step To Man," J. Wiley and Sons
Polanyi, Michael [1968], "Life's Irreducible Structure," Science, Vol. 160, pp. 1308-12, 21 June issue.

Roy, Rustum [1981], "Experimenting with Truth," Pergamon Press (1979 Hibbert Lectures).

Viscott, David, M.D. [1972], "The Making of a Psychiatrist," paperback, Packet Books, NY, ISBN: 0-671-54387-3.

Watzlavick, P., Beavans, J.H., and Jackson, D.D. [1967], "The Pragmatics of Human Communications," W.W. North and Co.

Wilson, E.O.[1965], "Time to Revive Systematics," Science, Vol. 230, No. 4731, 13 December.

Bull. Sci. Tech. Soc., Vol. 6, pp. 188-194, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

TECHNOLOGY EDUCATION: FROM WHERE TO WHAT?

Lee Smalley

What Should Happen

1. Technology Education should extend into the elementary school and colleges as a liberal arts subject.

   Although most of the focus up to now has been on junior and senior high schools, if technology is to be adequately understood it will have to start in the elementary school as they relate to the man-made world and extend into college where there can be a deeper understanding of the concept and process.

2. Technology Education should integrate other subjects into their activities, such as science, math, history, economics, etc.

   One of the advantages of technology education is that it is generally an applied subject. This may provide a way to apply areas such as indicated above plus English, psychology, and art.

3. Technology Education should structure some activities to connect all three time frames: past, present, and future.

   Young people need some rationale and some instruction in connecting all three time frames. Technology provides a very fruitful vehicle for this exploration. The future is especially important as they will need to focus on ends not just means.

4. Technology Education should focus some of their activities on information and attitudes associated with future job requirements.

   Jobs are going to become even more critical in the lifestyle of this coming generation. There must be some reminder that these people in school are preparing for a job: but which one?

5. Technology Education should relate to problem-solving activities that do not have a preconceived "right" answer.

   Many problems do not have one right answer, so the various tentative answers need to be tried out, to test their appropriateness. Areas in technology are particularly well adapted to this process and fit quite naturally into the total program.

6. Technology Education should provide leadership in showing how competency-based instruction can be achieved.

   Teachers must begin to think in terms of developing their instructional strategy to achieve competence in 90 percent of their subject matter to 90 percent of the students. This will require changes in attitude and techniques but America should require no less from its schools.

What Has Happened

1. Moved the name from manual training to industrial arts to technology education.

   Manual Training, coming into the schools in the 1890's and early 1900's, began to change to industrial arts in the 1920's. Some early attempts at reform began in the late fifties but it was not until the early 1980's that the technology education name began to be accepted by many of the teachers.

2. Moved the theme from manual skills to industrial orientation to technological literacy.

   The theme of this field has moved, somewhat behind, but still has moved with the change in the dominant characteristic of our society.

3. Moved the organization of the content from wood/metal/drawing to manufacturing, construction, communication, and transportation.

   Products, businesses, industries and services are no longer identified by a material or an occupation such as wood/metals/electricity. These four identified above are the systems by which human beings build a culture, and so these are the new organizers.

4. Moved the learning activity from exercises to individual take-home projects to simulation, enterprise, research and experimentation and group projects.

   No longer can we relate what we do in school to the outside world by having each student make a bread board or sugar scoop. Our society is more complex than that and so the activities should reflect this complexity.

5. Moved the method of teaching from demonstration/lecture to an individualized station-to-station approach.

   Much has been learned about how to individualize instruction and how people learn. The model where the teacher talks and the students listen does not do justice to the students or to the kind of people schools should produce. Equipping a station where there is a variety of objectives, media, instructional maerials and self tests should produce more independent and competent learners.

6. Moved the population from non-college bound males to representatives of a variety of student groups.

   If technology is one of the dominant forces for change in our society then all types of students should have some exposure to it. Vocational education may flow from technology education or this may be followed up by engineers, citizens, as hobbies, consumers, or scientists.

A Test for Technological Literacy

A great wealth of material has been written about technology education and more specifically the need for technological literacy. However, to our knowledge only two literacy tests have been developed in this area. One is by Dr. Jerry Richter in the area of communication. The other was a general technological literacy test developed by Anthony Gilberti, as a class project at Eastern Illinois University. Other content areas have been successful in developing literacy tests such as agriculture and computer science. "*If* *technological literacy is to be the theme for technology education (as the family is to be the theme for home economics), then there needs to be a test indicating, in broad terms, the level of technological understanding of individuals. Other fields of study such as music or biology, lend themselves to tests devised to show how much a person knows of a subject. So, it is assumed this method could also be used in the area of technology.*" (Smalley)

The purpose of this study was to derive criteria which could be used to generate a test which indicates (in broad terms) the level of technological literacy for a 12th grade high school student in the United States in the 1980's. Since technological literacy is a relatively new area, only a few "experts" could be found. The "experts" were identified by the work they have done in the area of technological literacy written in books, magazines, and professional conferences. One goal of the research was to achieve a consensus toward test criteria. Therefore, the Delphi survey method was used. The Delphi consisted of three rounds, with the final round including sample test questions.

The criteria agreed upon by the expert panel were as follows:

1. Connect past technological events to the present and be able to project alternative futures.
2. Be able to solve technological problems.
3. Be a wise consumer/decision maker concerning technological products/services.
4. Understand the implications of career choices in the field of technology.
5. Understand reading materials in technological areas written on the 10th grade level.
6. Apply technological knoweldge to a variety of human concerns and situations.
7. Knowledge of existing and emerging technologies.
8. Be able to evaluate technologies as to their appropriateness in our world.
9. Be able to understand and adapt to change brought about by technology.

Three multiple choice questions were developed for each of the nine criteria agreed upon. This original test was then administered by a variety of college and high school teachers to their students and results were tabulated. Based upon this data, many of the items were changed and the revised test is now ready for more extensive use.

This revised test has not been validated or standardized, but should be used as a teacher's tool to alert students and teachers to areas that are deemed important if one is to be technologically literate in the 1980's.

Technology Literacy Test (Revised)

___ 1. What invention was most important in the development of the first television set?

A. micro chip
B. solid state resistors
C. vacuum tube
D. satellite

___ 2. How many automobile companies were building cars in the U.S. in 1904?

A. 57
B. 32
C. 19
D. 4

___ 3. The American space exploration program was only possible because of the development of
A. new ceramic materials
B. computers
C. new navigational devices
D. all of the above

___ 4. Why has solar energy not achieved the widespread acceptance in 1985 that some had predicted 20 years ago?
A. conspiracy of the oil companies
B. acid rain has reduced the light intensity
C. still more expensive to produce
D. lack of government research funds

___ 5. Which step in problem solving would immediately follow the initial selection of a problem?
A. choosing the best solution
B. brainstorming
C. testing ideas
D. interview a researcher

___ 6. Which of the following would be most likely to get you up-to-date on a technical problem or solution?
A. subscribe to a monthly magazine
B. order a technical book
C. read a research report
D. interview a researcher

___ 7. If you had to buy a VCR in one week, and two brands were the same price, which one is most important to help you make a choice?
A. read the specifications
B. try each one for several days
C. ask people who had used one or both brands
D. buy the one that looked the best.

___ 8. You find a product you recently purchased is unsafe. What is the best option for you?
A. show it to all of your friends
B. take it back to the store where you purchased it
C. call the local newspaper with the story
D. don't buy the brand again

___ 9. When should you call an authorized repairman for your refrigerator?
A. when you hear a "funny" noise
B. when it won't work anymore
C. after you have tried to fix it
D. when nothing has gone wrong for six months

___ 10. Which of the following careers is/are most affected by the use of robots?
A. assembly line welder
B. painter of tractor parts
C. assembler of valve parts
D. all of the above

___ 11. Which of the following usually results with the introduction of computers in the manufacturing process?

A. more skilled than unskilled jobs are created
B. more unskilled than skilled jobs are created
C. fewer people work harder
D. most work less and get paid less

___ 12. Which occupational area has increased the largest percent in the last 10 years?

A. medical services
B. communication
C. manufacturing
D. sales and services

___ 13. Which of the following magazines would you refer to for an explanation of a current technological problem?

A. Fortune
B. Popular Science
C. High Technology
D. all of the above

___ 14. Which of the following problems would best be classified as a technological problem?

A. When should you paint your house?
B. What car would you buy?
C. How do you insulate a home?
D. Why are some people overweight?

___ 15. Read the following paragraph and then answer the question:

Develop a prototype of an office file server that can handle multimedia documents. That's the objective of an ESPRIT project being conducted by Battelle-Frankfurt. ESPRIT is the European Strategic Program on Information Technology. Its main purpose is to bring together European companies for research and development in pre-competitive areas to build more strength in thrust areas of common European interests.

Which of the following statements is true:

A. Europeans are going to mass produce a file server.
B. European companies are trying to develop a model for possible use in offices.
C. American companies are helping with the research and development.
D. This device will be built to handle documentation in several different languages.

___ 16. Robots are being used to produce automobiles because

A. they produce better products cheaper
B. there is a shortage of skilled labor
C. of Japanese technology
D. they are easier to use on smaller cars

___ 17. Which of the following will reduce the effectiveness of a passive solar system in a home?

A. small windows on the east and west sides
B. insulation in the ceiling and roof area
C. a good view through windows to the north
D. an overhang on the south side

___ 18. What is the single major change in the last few years that has made the personal computer practical?

A. availability of large computers to connect to
B. development of the microprocessor
C. development of more software
D. ability of young people to operate the personal computer

___ 19. What is a hologram?

A. laser produced 3D image
B. a telegram printed from a computer
C. a portable printer for a computer
D. a message received from a satellite

___ 20. Which term is NOT associated with personal computing?

A. Byte
B. K
C. Menu
D. R.O.D.

___ 21. CAD/CAM means

A. communication assisted digital/computer aided memory
B. computer assisted design and memory
C. communication aided design and manufacturing
D. computer aided design and manufacturing

___ 22. A third world country should not buy a high technology device until it

A. can pay for it
B. has the necessary infrastructure
C. sees another country like itself use it
D. can hire maintenance people

___ 23. Technology innovation

A. usually comes from individual inventors
B. is limited to the technical area in which it occurs
C. can give rise to multiple social and economic changes
D. is better understood by most people than in early America

___ 24. Which is an advantage of nuclear energy?

A. plant can be built anywhere
B. doesn't use scarce resources
C. plant is more dependable
D. cheaper to operate plants

___ 25. What is the difference in new cars from those produced 40 years ago?

A. can't be fixed as easily by "shade tree mechanics"
B. don't last as long
C. need more repairs
D. are cheaper to operate

___ 26. In the next 15 years in which type of jobs will there be the largest increase?

A. high tech industries
B. low pay/low skill
C. skilled labor
D. sales and services

___ 27. More education beyond high school will
- A. make you more specialized
- B. widen your options for a job
- C. put you behind others in seniority
- D. all of the above

Answers

1. C	10. D	19. A
2. A	11. B	20. D
3. D	12. D	21. D
4. C	13. D	22. B
5. B	14. C	23. C
6. D	15. B	24. D
7. C	16. A	25. A
8. B	17. C	26. B
9. A	18. C	27. D

Bibliography

M. Dyrenfurth, Literacy for a Technological World. (National Center for Research in Vocational Education, Columbus, OH, 1984).

A. Gilberti, Technological Literacy. Class project at Eastern Illinois University (Charleston, IL).

R. Hendricks, "A Technology Program for the 1980's." School Shop, April (1981).

J. Richter, The Construction and Partial Validation of a Scale to Measure Technological Literacy of Communication Technology. Doctoral Dissertation. West Virginia University, 1980. (University Microfilms Ann Arbor, MI, 1983.)

E. Ruina, The Weaver. Cambridge, Massachusetts: Massachusetts Institute of Technology (Winter, 1982).

R. Rumberger, Demystifying High Technology. (Columbus, Ohio: National Center for Research in Vocational Education, 1984).

L. Smalley, "A Proposal Written to the American Council on Industrial Arts Teacher Education to Develop a Technological Literacy Test." (University of Wisconsin-Stout, Menomonie, WI, 1982.)

LEE SMALLEY is Professor of Technical Education at the University of Wisconsin-Stout, 418 Harvey Hall, Menomonie, WI 54751, where he is active in teaching and research. He has produced one of the few tests for technology literacy.

Bull. Sci. Tech. Soc., Vol. 6, pp. 195-201, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

TECHNOLOGICAL LITERACY: SOME CONCEPTS AND MEASURES

Jon D. Miller

The Concept of Literacy

A conference on technological literacy is timely, needed, and symbolically appropriate to our society. There can be little doubt that we live in a time characterized by the rapid development and adoption of a wide range of technologies that have transformed the way we live our lives. I could cite volumes of statistics to demonstrate the pace of change, and I'm sure that you will hear most of them in the next few days. I think that the best way to convey the scope and impact of change over the last century is to describe briefly the life of my grandmother.

Julia Matney was born in 1887 on a hill farm in West Virginia, a couple hundred miles west of where we sit today. She was the fourth child, but the first girl, of 13 children and became responsible for raising the younger children after her mother died due to complications from the birth of the 13th child. The farm was a subsistence operation and the family produced everything it used. Once a year, her father would cut down a large walnut tree and take it to a mill for cash with which to buy needles and pots and pans.

During Julia's life, she saw the first railroad come to the county in which she lived and she reported that several people were killed that day because the steam engine scared the horses that had pulled the wagons and buggies that had been used to bring people to see this new thing. She saw the invention of the automobile and saw the effect of this technology on society. She was often a passenger in a car, but never learned to drive. She saw the invention of the airplane and, in her latter years, was often an airline passenger.

During her life, she witnessed the invention and growth of radio, and later television. Through these electronic eyes and ears, she followed two world wars, several lesser wars, and the emergence of the technology of the cold war. And, she lived long enough to see--through television--Neil Armstrong step on the moon.

Julia was an extraordinary lady and she lived during an extraordinary time. She experienced a high level of technological change throughout her life. She was minimally literate in that she could read and write--and apparently taught reading and writing to children in her community--but she was not technologically literate in any possible sense of that term. She admired the new inventions around her and found that they generally improved the quality of her life, but she did not know how or why they did their magic.

Julia's plight is symbolic of her generation, and largely of our own. Her life and times provide a useful framework for thinking about what we mean when we talk about technological literacy. Her life also illustrates some of the barriers or problems that will be encountered in seeking to foster technological literacy.

Basic Literacy

It is important to think about the meaning of literacy. While the term has been used to cover a wide array of levels of knowledge, most educators would agree that basic literacy denotes the ability to read and write at a level that allows an individual to function--at least minimally--within our society. This is a useful definition and one that we will want to return to later.

Basic literacy is a prerequisite to scientific or technological literacy. If you cannot read and comprehend the descriptions and explanations of the changes around you, you become inevitably the captive of television and a believer in technological magic.

My grandmother Julia is an excellent example of this problem. Her formal education was limited and, while she could read simple text like that found in a newspaper, her technical vocabulary was limited and she could not effectively use or follow technical manuals for appliances and other machines around her. She simply accepted the technologies around her much as she accepted the weather--as forces not susceptible to understanding or control.

While our elementary school textbooks describe the United States as a nation with universal literacy, an increasing number of studies point to serious deficiencies in basic adult literacy. Several empirical studies have concluded that at least 20 percent of American adults are functionally illiterate today (Northcutt, 1975; St. John-Hunter and Harman, 1979). In short, one in five adults cannot read and write at a level sufficient to read bus schedules, warranties, or medical instructions.

Scientific Literacy

Although the subject of this conference is technological literacy, it is important to turn briefly to a discussion of scientific literacy. As a term, the roots of scientific literacy are longer and deeper than technological literacy and have been described elsewhere (Graubard, 1983). There is an important definitional parallel, however, between basic literacy and scientific literacy. If basic literacy refers to the ability to read and write at a level that allows an individual to function in his or her society, then scientific literacy should be defined as the ability to read, comprehend, and communicate about science at a level that would allow an individual to function effectively in a scientific culture like our own (Miller, 1983a, 1983b).

In an article in a 1983 issue of Daedalus, I suggested a three-dimensional definition of scientific literacy. I suggested that to be classified as scientifically literate, an individual should understand the scientific approach to evidence and theory building, some of the basic terms or constructs employed in modern science, and some of the ways in which science and society impact each other. This definition was a first effort and was shaped in part to utilize some existing data from a 1979 study of a national sample of adults. It can and ought to be re-examined and improved.

Using some 1979 data and the definition outlined above, an analysis indicated that only seven percent of adults in the United States qualified as scientifically literate (Miller, 1983b). The implications of this finding are serious, but beyond the scope of this paper. In a paper to be presented at the 1986 annual meeting of the American Association for the Advancement of Science (AAAS), I will present some new data updating the previous estimates and suggest some revisions to the definition.

The important point for this discussion is that scientific literacy is conceptually distinct from technological literacy and that only about one in 14 Americans meet a minimal definition of scientific literacy.

Technological Literacy

What, then, do we mean by technological literacy? In the context of our previous discussions of basic literacy and scientific literacy, I would propose that technological literacy be defined as an understanding of the application of science and engineering to the solution of concrete problems. Conceptually, I would view technological literacy as a continuous or internal variable and would expect that we could identify some threshold level that we might agree would be the minimal level of understanding needed to function effectively in our society. In practice, given our current measurement technologies, we may find it useful to think categorically in terms like technologically illiterate, minimal technological literacy, and a higher level of technology.

In thinking about the substance of technological literacy, it is important to emphasize the ability to understnd a basic set of terms that are necessary for communication about technological issues, a comprehension of how some of the major technologies in our environment work, a sense of technology as an ordered and rational effort to solve definable problems, some understanding of the functioning of human organism, and some recognition of the interaction between people and the technologies we use. The technologically literate person should understand how basic technologies work, which aspects are changeable and which are not, and some of the impacts and implications of major technologies. The technologically literate person should understand that in democratic societies, citizens can have some say in which technologies are advanced and which are restrained.

Some Measures of Technological Literacy

Having suggested some of the components of a definition of technological literacy, it is reasonable to ask what measures we have of technological literacy and what proportion of the American people qualify as technologically literate. These are indeed reasonable questions and there are some data that can give us insights into the levels of understanding extant among the American people, but I would also enter a note of caution. The concepts of scientific literacy and technological literacy are important to our society and it is necessary that considerable thought go into the definition of these constructs and that measurements be collected after careful definition. To date, all of the measures in the literature and the estimates that I will share with you today are based on secondary analyses of data collected for other purposes. If we value an accurate measurement of these concepts, then we must soon decide to devote some resources to the explicit definition and measurement of these constructs.

Now, let us turn to some measures that come from a recent national survey of approximately 2000 adults.[1] The survey was supported by a grant from the National Science Foundation (SRS-8517581) and was conducted by telephone from the Public Opinion Laboratory. A more complete analysis of the data will appear in the National Science Board's report Science Indicators--1985.

---

[1] The Public Opinion Laboratory national sample is based on 150 primary sampling units and uses a random-digit-dialing procedure to select households within each PSU. Within each household, one adult (aged 18 and over) respondent is randomly selected. The interviews averaged 30 minutes in length and a completion rate of 81 percent was obtained for the 1985 study.

As suggested earlier, one aspect of technological literacy should include an understanding of some of the basic terms needed to communicate about technological issues. In that vein, the 1985 study asked each participant whether they felt that they had a clear understanding of, a general sense of, or little understanding of four terms that I would count as important to technological literacy: radiation, computer software, GNP, and how a telephone works. The results indicated that 31 percent of the American people think that they have a clear understanding of radiation, 27 percent think that they have a clear understanding of the gross national product, 24 percent think that they have a clear understanding of the meaning of computer software, and only 19 percent believe that they have a clear understanding of how their telephone works (see Table 1).

Table 1
Public Understanding of Selected Technical Terms.

	Level of Understanding		
	Clear	General	Little
Radiation	31%	51%	19%
GNP	27	22	50
Computer software	24	33	43
How a telephone works	19	48	33

N - 1992

It is also important for the technologically literate citizen to understand that technology is a rational effort to apply scientific knowledge to the solution of definable problems. Toward this end, the technologically literate citizen should not place great reliance on luck or eschew planning. To assess these dimensions of technological literacy, the 1985 study presented each respondent with a series of statements and asked each person to indicate whether they strongly agreed, agreed, disagreed, or strongly disagreed with each statement. It is a methodology with a long and respectable history.

The results indicated that 78 pecent of American adults rejected the idea that "it is not wise to plan ahead because many things turn out to be a matter of good luck or bad luck anyway" and 56 percent rejected the idea that "some numbers are especially lucky for some people" (see Table 2). While it is somewhat comforting to find that a majority of the American people reject luck as the driving force of their lives and of society, it is important to remember that each percentage point in a national survey represents 1.7 million people. In real numbers, these results indicate that approximately 37 million Americans eschew planning for the future and that almost 75 million believe in lucky numbers. While these numbers may be good news for the people who run lotteries, they are not a positive reflection on the technological literacy of our society.

A technologically literate citizen should understand enough about the human organism to be able to make reasonable judgments about the advancement of his or her own health. The recent growth in health magazines and newsletters indicates that a growing proportion of the American people see this kind of knowledge as important. The 1985 study included a pair of statements that capture two aspects of health knowledge and awareness. One statement focused on the health implications of smoking and found that 95 percent of American adults agreed that "smoking causes serious health problems." At the other end of the spectrum, only 18 percent of American adults were willing to disagree with the statement that "there are some good ways of treating sickness that medical science does not recognize" (see Table 2). It is not clear whether this result is an endorsement of folk medicine, a mass conversion to acupuncture after the Bears victory in the Super Bowl, or a vote of no confidence in the medical profession. Whatever its origins, it appears to be inconsistent with the idea of technological literacy.

Table 2
Public Acceptance of Selected Technological Ideas.

	Agree	Not Sure	Disagree
It is not wise to plan ahead because many things turn out to be a matter of good or bad luck anyway.	20%	2%	78%
Some numbers are especially lucky for some people.	40	4	56
Smoking causes serios health problems.	95	1	3
There are good ways of treating sickness that medical science does not recognize	75	8	18
Rocket launchings and other space activities have caused changes in our weather.	41	12	47
It is likely that some of the unidentified flying objects that have been reported are really space vehicles from other civilizations.	43	11	46
N = 1992			

A third dimension of technological literacy might include an ability to distinguish between likely scientific or technical results and fictional or hearsay accounts. The 1985 study asked each respondent to strongy agree, agree, disagree, or strongly disagree with the statement that "rocket launchings and other space activities have caused changes in our weather" and the statement that "it is likely that some of the unidentified flying objects that have been reported are really space vehicles from other civilizations." In both cases, slightly fewer than half of American adults were willing to disagree with the statement (see Table 2). These responses suggest a substantial level of confusion between real or likely technologies and fictional technologies.

In summary, this brief review of the knowledge of selected terms and ideas suggests that some portion of the American public is informed about technological issues, but that a substantial portion is not well informed in these areas. It may be useful to seek a summary measure of this kind of information about technology generally and about specific technologies.

An Index of Technological Literacy

The ten items just discussed represent a cross-section of information that might be considered relevant to what we would call technological literacy. It is possible to combine these ten items into a simple index and to examine the distribution of the index for the adult population of the United States and for various segments of the population.

As a preface to an examination of the data, however, two points need to be made. First, the ten items included in this index are a reasonable reflection of some of the major areas that ought to be included in the substance of technological literacy, but the 1985 study was designed for other purposes and this index is not exhaustive of the areas that are implied by a label like technological literacy. This index should be viewed as an estimate of the likely distribution of technological literacy in American society if a more comprehensive measure were to be used. Second, it is important that those of us here turn our attention to the construction of measures of both scientific and technological literacy that can command consensus among our colleagues. Once we have developed generally acceptable measures, we can then begin to track changes in the level of scientific and technological literacy. Without some agreed upon measures of constructs like technological literacy, we will have little chance of knowing whether our programs are working and for which segments of our society.

Looking at the data we do have, however, we can make some estimates of the level of technological literacy in the United States. The mean score on the index for all American adults was 4.4, which is slightly below the midpoint for the scale. Sixteen percent of American adults earned a score of two or lower, representing almost 28 million adults (see Figure 1). Approximately half of American adults earned scores of three, four, or five. Slightly over a quarter of adults scored above the midpoint of the index--six or more--and only two percent of American adults were able to score a nine or ten on the index.

In addition to the aggregate distribution of technological literacy in the United States, it is possible to look at the mean scores for selected segments of the population. Using the ten point index described above, an analysis of several demographic categories indicated that the level of technological literacy is significantly higher for men than women and for persons with more formal education (see Table 3). Citizens younger than 25 or older than 65 were significantly less likely to be technologically literate than were citizens in the middle age groups.

The overall level of performance is not satisfactory. The items included in the index were not inherently difficult. It is not inherently difficult. It is not unreasonable to expect citizens of a mdoern democratic nation to understand terms like radiation or GNP. After all, these are terms that have been used in numerous presidential press conferences, newspaper stories, and radio and television newscasts. It is not unreasonable to expect citizens of a democratic state that have the possibility of participating in the formulation of public policy to favor planning over luck. It is clear that there is a lot of work to do

Implications for Science and Mathematics Education

What are the implications of these data for science and mathematics education in the United States? I believe that three points merit discussion.

First, looking at the scores on the index of technological literacy by age group, it is clear that young Americans just emerging from their formal eudcation are as likely to be technologically literate as somewhat older adults. This result suggests that the years of formal education are not producing a high level of knowledge that we might include in a definition of technological literacy.

Second, all of our literature concerning learning suggests that the years of formal education from kindergarten through high school should be the optimal period for establishing a base of technological literacy on which later learning can occur. Several of the panels at this conference will address the question of improving the formal education experience in this regard.

Third, the pace of technological change demands a vigorous informal education program for adults to maintain scientific and technological literacy. There is good empirical evidence that many adults today use science and technology museums, science magazines, and science programming on television to retain whatever level of literacy they may have acquired through earlier training (Dimmock, 1985). We need to think carefully about how to make the informal learning process more effective and several panels at this conference will be addressing facets of this question.

Implications for a Democratic Society

Finally, we come to the issue of technological literacy and citizenship. The public policy agendas at the national and state levels are full of issues and problems that require some level of technogical literacy to support minimal discourse. How can a citizen who does not understand the nature of radiation participate usefully in a discussion of the disposal of nuclear power plant waste? How can a citizen who does not understand the idea of GNP evaluate the arguments of candidates about the rate of economic growth?

Governmental support for the development of new technologies and governmental regulation of the uses of technologies are realities. And, however, imprecisely, government in our society is ultimately controlled by the citizenry. Many citizens appear willing to stand aside and allow others to run the show for the present, but the history of the American political system is clear--an aroused electroate can change the leadership and direction of government when it wishes.

We cannot, and should not, try to avoid the democratic system. These data do not argue for the creation of a Science Court or other mechanisms to remove the mass public from the task of increasing and improving technological literacy in the United States.

Bibliography

Dimmock, Katherine. 1985. Models of Adult Participation in Informal Science Education. A dissertation completed at Northern Illinois University, DeKalb, Illinois.

Graubard, Stephen R. (Ed.), 1983. Scientific Literacy. Daedalus, 112:2.

Miller, Jon D. 1983a. The American People and Science Policy: The role of public attitudes in the policy process. New York: Pergamon Press.

_____. 1983b. Scientific Literacy: A Conceptual and Empirical Review. Daedalus, 112:2:29-48.

Northcutt, Norvell et al. 1975. Adult Functional Competencies: A Summary. Austin: University of Texas Division of Extension.

St. John-Hunter, Carmen and David Harman, 1979. Adult Illiteracy in the United States. New York: McGraw-Hill.

JON D. MILLER is Director of the Public Opinion Laboratory at Northern Illinois University, DeKalb, IL 60115.

Bull. Sci. Tech. Soc., Vol. 6, pp. 202-209, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

MEASURING TECHNOLOGICAL LITERACY: PROBLEMS AND ISSUES

Paul W. DeVore

Measuring Technological Literacy

There are a number of reasons to engage in efforts to measure technological literacy. The more obvious reasons focus on the need to provide information about the current types and levels of technological literacy extant among the citizens. With an informed baseline educators and others would have information on which to base decisions about curriculum and instruction in technology. Nationally normed tests of technological literacy can provide the means to evaluate education programs and aid in determining public policy relating to the design, implementation, development, funding and evaluation of programs for the enhancement of technological literacy.

Problems and Issues

There are two main questions that must be addressed concerning the measurement of technological literacy. They are the same questions that must be asked in any measurement or evaluation effort. The primary question is "What to measure?" The secondary question is "How to measure it?"

What to Measure? Overview

In the United States and elsewhere there is an increasing concern among educators and others about science education, technology education, scientific literacy and technological literacy. There have been pronouncements, conferences, articles, monographs and new curricula develop'd to address these issues. Yet, as reviews of information from these activities indicate, there is considerable confusion as to what is meant by either scientific or technological literacy; there is no common agreement.

There are no agreements as to definitions of these fields of human endeavor and there is extensive confusion about the relationships between science and technology. Some writers and students of the problem believe science, engineering and technology are related but distinct enterprises, while others believe all are part of the field of science with mathematics, in some way, an important component of each.

If the problem of measuring technological literacy is to be engaged and possibly solved, some effort must be directed toward defining and/or describing the fields of science and technology so criteria can be developed to differentiate between them. This is a necessary first step if public policy debates are to provide any semblance of reasonable solutions. It is also a necessary first step if those in education are to navigate with a clearer vision while attempting to meet their responsibilities in designing and developing appropriate education programs. In addition, it seems necessary to enhance and focus the dialogue concerning science and technology so more appropriate research agendas related to issues surrounding scientific and technological literacy can be established. Our current intellectual confusion must be transcended and definitions, structures, and content determined and agreed upon before any meaningful effort can be directed toward the measurement of technological literacy.

Part of the problem confronting those who are concerned about technological literacy and desire to structure programs of study and means of measurement and evaluation is the diversity of the views people have about technology. Everyone agrees that there is something we call technology and that there is something called technological literacy. But to enter the realm of scientific measurement, we must be objective and precise and we must reach some common agreements.

There are many ways of structuring a program of technological literacy. An economist would focus on the production function, an engineer on the technical, an anthropologist on the cultural and a sociologist on the social. None of these approaches is sufficient to structure a program of technological literacy today. What seems to be needed is a focus which has been evolving from the new and evolving discipline of technology, namely,

> *"the study of the creation and use of technical means*--tools, machines, techniques, technical systems--and the behavior of technological systems in relation to people, their societies, the environment and the civilization process."*

A technological literacy focused on the creation, use, behavior, and relational factors of technical means provides a base upon which to develop programs of study for the preparation of intelligent and capable citizens of a democratic society and at the same time directs attention to the primary content and process categories required for answering the question: "What to measure?"

To place the foregoing definition in focus and to provide a perspective from other more standard forms of literacy, the question can be asked: "What does it mean to be literate in French or Russian?" A typical reply would be that the student should be able to speak, read and write in the French or Russian language, implying a knowledge and understanding of the words, symbols, syntax and structure of the language as well as the ability to perform using the language. It also implies a knowledge and understanding of the history and culture of the countries where the language is primary. Similar criteria would apply with respect to technological literacy.

The definition of technology provides clues to the learning activities that would be meaningful, cumulative, and have long-term application. For instance, studies concerning the creation and evolution of technical means and systems would provide insight into the relation of these means and systems to human beings and society, thus establishing data for the derivation of concepts and principles concerning their behavior on which assessments and predictions could be based.

Understanding how technical means are created would aid in improving our ability to design and create appropriate technical means for our communities. Citizens knowledgeable about the use of technical means and systems would have better insight into the best or most appropriate procedures as well as problems associated with the adoption and use of technical means by society. The latter knowledge could then be used in the design of alternatives to our present problem-plagued technological systems or for the redesign of current systems to attain a greater degree of compatibility with human beings, their communities, and the environment.

---

*Technical means is used by the author rather than technology. Technology is the discipline or field of study (-ology); technical means the elements created and used which are the object of study.

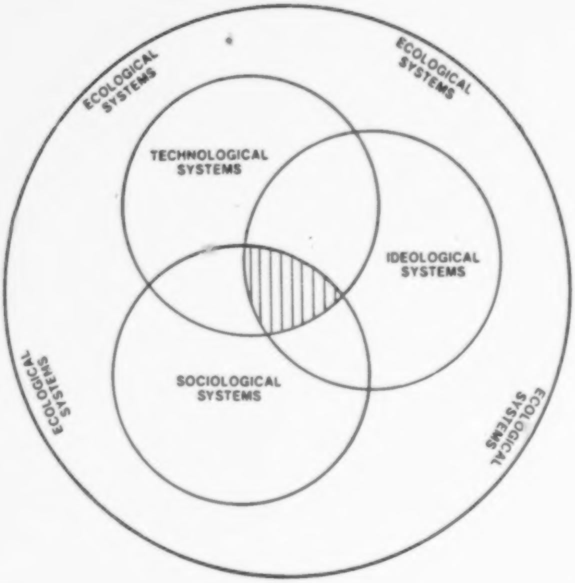


Figure 1. The interrelationship of systems--technological, sociological, ideological and ecological. (DeVore, P.W. Technology: An Introduction. 1980, p. 339.)

Knowledge of the technical aspects of systems would focus on the behavior of material transformation processes. However, the operational behavior of systems and subsystems would focus on techno-social relationships, perhaps one of the more complex categories of learning. The techno-social relationships would concern the relation of technical means and systems to individuals, communities, work and employment, and the natural environment. Here, the focus of learning would be on the identification and use of concepts and principles for assessing and predicting the effects of the introduction of a new technical means into a social and natural context. Involved would be the processes of technological assessment and the prediction of probable impacts and risks.

Other categories implied by this focus would be studies about evolving and future technical means and public policy concerning the adoption and use of new technologies. Included in the later would be studies concerning employee adaptability to technological change and the appropriateness of given technical means and systems with respect to quality of life and sustainability of communities.

What to Measure? Structure and Content

Categories from which to derive content for the study of technology and on which to base a table of specifications for the measurement of the technological literacy of capable and effective citizens can be determined from the definition. The definition provides a conceptual structure that organizes the components into a meaningful system showing relationships.

Emerging from an analysis of the definition is the realization that there are four basic interrelated systems that determine the structure and ethos of any society. There are: the ideological, sociological, technological and ecological systems shown in Figure 1.

The diagram in Figure 1 provides a structure which illustrates the major systems and their relationships. In addition to a system relational diagram there is a need for a structure which illustrates the dynamics of the processes of the system. The participatory processes in which people are involved as they pursue the design of technological systems to serve social purposes are shown in Figure 2. The first diagram answers questions about systems and relationships while the second diagram illustrates the dynamics of the content by showing the relationships among the systems--ideological, sociological and technological--and the human intellectual processes involved in the evolution of the idealogical, sociological, technological and ecological systems and society. Three critical processes are involved--valuing, enabling, and assessing.

Finally, any analysis of technology for the purpose of determining content and processes for curriculum and instruction in the technologies or for measuring technological literacy requires a structure which identifies the primary elements of technological systems and their relationships. The matrices of Figures 3 and 4 illustrate an approach for the identification of structure and content for these purposes.

There are three dimensions to the matrix. These consists of (1) components, which operate in certain (2) contexts, at (3) various levels of complexity. There are technical components and social components. Technical components consist of resources, materials, tools, machines, energy, power and information. Social components consist of human elements including work skills, intellectual processes, occupations, environmental relationships, and organization and management of technical systems, among others. These vary depending on people and the structure of the sociological and ideological systems to which a given technical system relates and the ecological system in which these exist.

The various components are structures and used by people in different ways in three interrelated dynamic contexts, communication, production, and transportation systems. These systems exist in all cultures regardless of the level of sophistication of the culture. The relationship of components and contexts is illustrated on two of the axes of Figure 4.

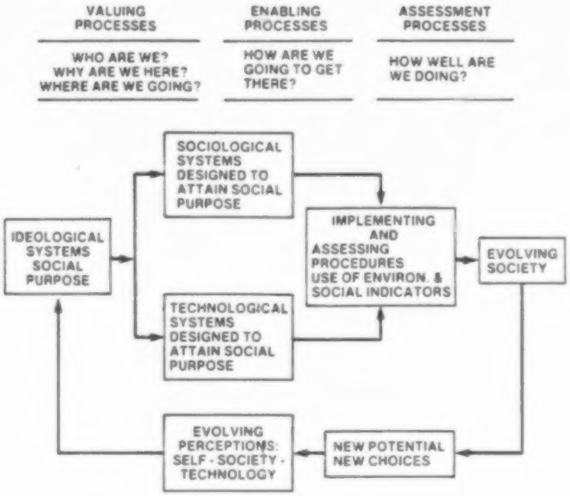

VALUING PROCESSES
WHO ARE WE? WHY ARE WE HERE? WHERE ARE WE GOING?
ENABLING PROCESSES
HOW ARE WE GOING TO GET THERE?
ASSESSMENT PROCESSES
HOW WELL ARE WE DOING?
SOCIOLOGICAL SYSTEMS DESIGNED TO ATTAIN SOCIAL PURPOSE
IDEOLOGICAL SYSTEMS SOCIAL PURPOSE
IMPLEMENTING AND ASSESSING PROCEDURES USE OF ENVIRON. & SOCIAL INDICATORS
EVOLVING SOCIETY
TECHNOLOGICAL SYSTEMS DESIGNED TO ATTAIN SOCIAL PURPOSE
EVOLVING PERCEPTIONS: SELF - SOCIETY - TECHNOLOGY
NEW POTENTIAL NEW CHOICES

Figure 2. The evolution and relationship of technological systems and social purpose. (DeVore, P.W. Technology: An Introduction. 1980, p. 340.)

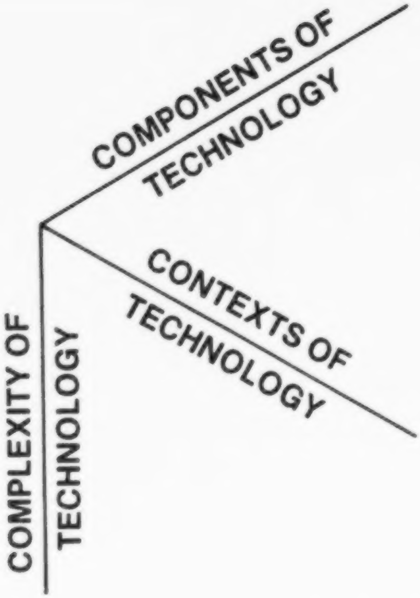

COMPONENTS OF TECHNOLOGY
CONTEXTS OF TECHNOLOGY
COMPLEXITY OF TECHNOLOGY

Figure 3. Technology--Elements of an infrastructure. (DeVore, P.W. Technology: An Introduction. 1980, p. 340.)

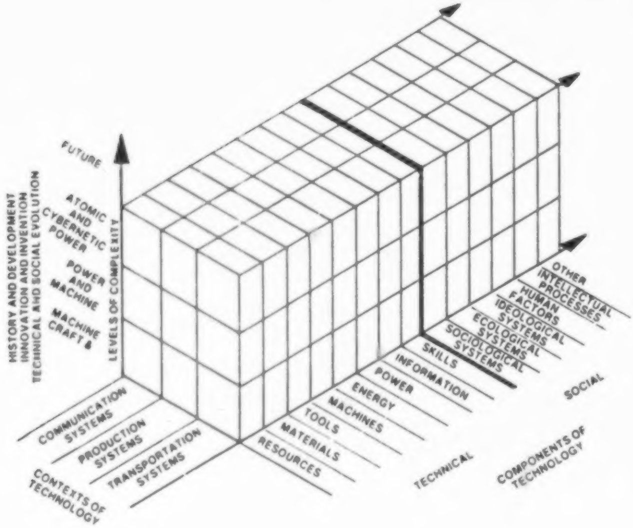

FUTURE
ATOMIC AND CYBERNETIC POWER
POWER AND MACHINE
MACHINE CRAFT &
HISTORY AND DEVELOPMENT
INNOVATION AND INVENTION
TECHNICAL AND SOCIAL EVOLUTION
LEVELS OF COMPLEXITY
COMMUNICATION SYSTEMS
PRODUCTION SYSTEMS
TRANSPORTATION SYSTEMS
CONTEXTS OF TECHNOLOGY
RESOURCES
MATERIALS
TOOLS
MACHINES
ENERGY
POWER
INFORMATION
SKILLS
SOCIOLOGICAL SYSTEMS
ECOLOGICAL SYSTEMS
IDEOLOGICAL SYSTEMS
HUMAN FACTORS
INTELLECTUAL PROCESSES
OTHER
TECHNICAL
SOCIAL
COMPONENTS OF TECHNOLOGY

Figure 4. Technology--An infrastructure. (DeVore, P.W. Technology: An Introduction. 1980, p. 341.)

The evolution of technological systems is illustrated by the third axis of the matrix labeled complexity. The design of the matrix provides a means to illustrate that technological systems have evolved from early tool making, through the craft era, to the power and machine period of industrialization, to the atomic and cybernetic stage of the last half of the twentieth century. Continual evolution is indicated by the word future and the extension of the axis.

The structure illustrated provides a means to identify structure and content for curricula for the study of technology and the measurement of outcomes from the study of technology--technological literacy. The integral nature of the matrix focuses attention on the necessity of learning not only about systems and their relationships, but the facts, concepts and intellectual processes of the subsystems and numerous components from the historical, contemporary and future perspectives as well. The marix implies very clearly that it is not possible to be technologically literate without becoming involved with technical knowledge and technical systems and their elements and operation. The same is true for those who would propose programs for attaining technological literacy that are not invovled with human beings, social knowledge and social systems. Such approaches will be abortive and interfere with the development of the kind of programs required to attain true technological literacy with the goal of returning the control of technical means to people for human purposes.

What to Measure? Intellectual Factors

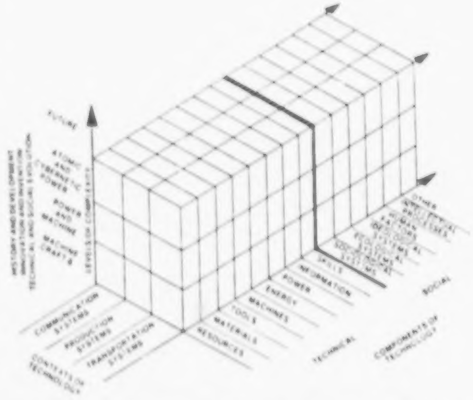
The creation of new technical means and systems is an intellectual effort of high order. The character of thinking involved in creating and using technical means is different from that involved in the creation of a new philosophy, a new religion, an alternate form of government or a new law or social policy. Thinking in creating new technical means is problem specific and environmentally specific, concerned with efficiency and the relation of elements in the behavior of a total system. The latter engages the question of "why" one system is more effective than another as well as "how" the system works or behaves. The goal is predictability of outcome and performance.

Those involved in decisions about the creation and use of new technical means are involved directly in human, social and environmental problems and issues. These contexts place constraints and limits on the solutions and the means that can be used. They also add valuing to the intellectual processes associated with creating and using technical means, thus extending the range of questions, problems, and issues beyond the narrow perception of technology as things, placing the question of knowledge and technology within a new realm of perception.

All knowledge created in various fields of human endeavor involves certain modes of inquiry, modes of thinking, or intellectual processes. The field of technology is no different. An investigation by Dr. Harold Halfin identified seventeen methods of inquiry of the technologist. They are defined as "functional or intellectual skills which are the randomed or ordered methods, strategies or operations used by a technologist to accumulate knowledge about an artifact or to solve a technological problem" (p. 205). Halfin lists the functional or intellectual skills as:

A.	B.	C.
A technologically literate person would have intellectual skills and abilities in these categories →	about these systems and components of technical means →	and be able to apply their intellectual skills and abilities within the context of interrelated systems at local, national and global levels

1. Knowledge of specifics
2. Knowledge of ways and means of dealing with specifics
3. Knowledge of universals and abstractions in a field
4. Intellectual abilities and skills including
   Comprehension
   Translation
   Interpretation
5. Application
6. Analysis
7. Synthesis
8. Evaluation
   (Bloom, P.)


FUTURE
ATOMIC AND CYBERNETIC POWER
POWER AND MACHINE
MACHINE CRAFTS
HISTORY AND DEVELOPMENT
INNOVATION AND INVENTION
TECHNICAL AND SOCIAL EVOLUTION
LEVELS OF COMPLEXITY
COMMUNICATION SYSTEMS
PRODUCTION SYSTEMS
TRANSPORTATION SYSTEMS
CONTEXTS OF TECHNOLOGY
RESOURCES
MATERIALS
TOOLS
MACHINES
ENERGY
POWER
INFORMATION
SKILLS
TECHNICAL
SOCIOLOGICAL SYSTEMS
ECOLOGICAL SYSTEMS
IDEOLOGICAL SYSTEMS
HUMAN FACTORS
PSYCHOPHYSICAL PROCESSES
OTHER
SOCIAL
COMPONENTS OF TECHNOLOGY

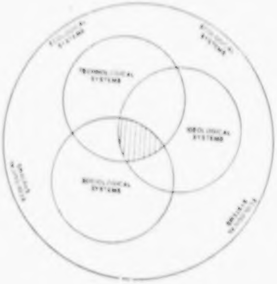

TECHNOLOGICAL SYSTEMS
IDEOLOGICAL SYSTEMS
SOCIOLOGICAL SYSTEMS
ECOLOGICAL SYSTEMS

Figure 5. Parameters for determining "what to measure."

1. defining the problem or opportunity operationally
2. observing
3. analyzing
4. visualizing
5. computing
6. communicating
7. measuring
8. predicting
9. questioning or hypothesizing
10. interpreting data
11. constructing models or prototypes
12. experimenting
13. testing
14. designing
15. modeling
16. creating
17. managing (p. 207)

What to Measure? A Composite

The question of measuring the technological literacy of citizens will involve several dimensions. These dimensions can be derived from the Taxonomy of Educational Objectives: The Classification of Education Goals Handbook I: Cognitive Domain by Bloom et al. Using the taxonomy constructed by Bloom and others, the matrix presented in this paper, the functional or intellectual skills identified by Halfin, and the knowledge of the systems and their interrelationships discussed previously, it is possible to begin to identify the types and levels of technological knowledge as well as the contexts within which the knowledge is applid. The latter are the human, social and environment contexts where decision making, problem solving and valuing are required at a high order. These dimensions establish the parameters for answers to the question "What to measure?" The relational diagram below illustrates the three main components of the "What to measure?" reservoir (Figure 5).

How to Measure?

There are few significant problems associated with the how to measure question. For the most part once the question of what to measure?, who to measure?, and when to measure? have been determined, the question of how to measure? can be answered.

Answers to the questions of what?, who? and when? set criteria and parameters for the how to measure? question and determine the structure of the table of specifications for the measurement of technological literacy.

Measuring the complete range of technological literacy will probably require the use of testing procedures ranging from multiple choice, matching, rank ordering, completion, true/false, problem solving, simulation and games.

The size and complexity of the task suggests the need to investigate the possibility of creating computer programs for testing whereby individuals can evaluate themselves at any time and maintain records of their progress toward the goal of being technologically literate.

References

B.S. Bloom (ed.). Taxonomy of Educational Objectives (Longmans, Green and Company, New York, 1956).

P.W. DeVore. Technology: An Introduction (Davis Publications, Inc., Worcester, 1980).

H.H. Halfin. Technology--A Process Approach (West Virginia University Technology Education Program. Unpublished doctoral dissertation, Morgantown, 1973).

L. Winner. Autonomous Technology (MIT Press, Cambridge, 1977).

PAUL W. DeVORE is a Professor in the Department of Technology Education at the University of West Virginia, Morgantown, WV 26506.

Bull. Sci. Tech. Soc., Vol. 6, pp. 210-218, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

EMPOWERMENT OF PEOPLE: THE EDUCATIONAL CHALLENGE OF SCIENCE FOR SPECIFIC SOCIAL PURPOSES (SSSP)

David Layton

Introduction

Writing about public understanding of science, John Ziman has identified an important difference in viewpoint between 'insiders' and 'outsiders.' For practitioners of science, those engaged in 'making knowledge,' and working on science from the inside, the emphasis is predominantly 'on the possibilities of discovery and of validation.' In contrast, the outsider's view is 'overwhelmingly instrumental.' Science is of interest to non-scientists primarily becuase of its potential for use.

Ziman's conclusion is that there is 'a serious mismatch between the interests of those who are already inside science, and the motives of those whom they would like to draw in' (Ziman, 1984, pp. 184-5) i.e. the general public whose apparent scientific inattentiveness and illiteracy gives scientists cause for concern (Royal Society, 1985).

The educational implications of this mismatch are the subject of this paper. The perspectives of 'insiders' lead them 'to structure the science curriculum around the central cognitive themes' and these are characterized by abstraction and disconnection from everyday contexts. In what follows it will be argued that if science is to be returned to the people to assist their empowerment in relation to the solution of problems with a science/technology dimension, then it will need to be structured in ways that relate more effectively to the interests of specific groups of adults.

The paper has four sections. First, historical evidence is presented about the dispositions to science which have characterized the laity, particularly in a period when non-professional interest in science was strong. Second, contemporary evidence on adult learning and understanding of science is briefly reviewed. Third, the results of recent research into the scientific understanding and the perceived needs for science of specific groups of adults are described. Finally, the implications of this research for the nature of institutional provisions necessary to enable adults to achieve empowerment are sketched.

The Historical Origins of Science for Specific Social Purposes (SSSP)

Adult indifference to, and lack of understanding of, science has not always been the case. On this subject the early decades of the nineteenth century in Britain provide some suggestive insights. This was a period when a writer in the Edinburgh Review could claim that 'the sacred thirst for science is becoming epidemic' (Hindley, 1825, p. 499) and the London Magazine could report that, 'In every town, nay almost in every village, there are learned persons running to and fro with electric machines, galvanic troughs, retorts, crucibles and geologists' hammers' (Anon., 1828, p. 136). Indeed, it is arguable that scientific knowledge was more widely diffused amongst the adult literate population in Britain then than at any subsequent time.

Certainly, there was an abundance of texts on scientific subjects. Analysis of the contents of institutional libraries, such as those of Mechanics' Institutes, confirms this (Hinton, 1980), as does the published list of school books whose purchase could be assisted by government grant. The works ranged over geology, botany, zoology, anatomy, chemistry, natural philosophy, mechanics, optics, hydrostatics and pneumatics; they also differed in mode of literary presentation--catechetical, conversational, lexigraphical, encyclopaedian, as well as more familiar narrative and didactic forms (Layton, 1973, pp. 105-112).

The popular appeal of science in these early years of industralization and urbanization in Britain cannot be explained in terms of any single motivation or social purpose (Inkster and Morrell, 1983). Studies of science in a variety of provincial settings have established that different social groups saw in science an instrument for the fulfillment of their specific intents. Alternatively, or additionally, the members of one social group could have multiple reasons for making science their dominant concern. In a detailed study of science in Manchester, the Athens of the Industrial revolution, Arnold Thackray has identified seven reasons why members of the city's Literary and Philosophical Society chose science as their preferred intellectual genre. It has possibilities 'as polite knowledge, as rational entertainment, as theological instruction, as professional occupation, as technological agent, as value-transcendent pursuit, and as intellectual ratifier of a new world order' (Thackray, 1974, p. 686).

For those from other segments of a highly differentiated society, science had different meanings. Radicals such as Thomas Paine saw science and science education as the keys to freedom, truth and progress (Simon, 1972, pp. 12-13). Richard Carlisle's Address to Men of Science (1821), written whilst imprisoned in Dorchester jail for publishing Paine's The Age of Reason, similarly looked to science to banish superstition and persecution from the face of the earth (Wiener, 1983). Rowland Detrosier, 'a working-class infidel' who lectured on chemistry, natural philosophy, astronomy and morals, saw science as a talisman for the poor to be used against false prophets and to dispel ignorance (Williams, 1965).

Science, then, was a multi-faceted resource capable of serving both conservative and radical purposes. At one extreme it was used to confirm religious beliefs; at the other, to undermine them. For some its value-transcendent characteristics were a unifying balm for a society troubled by unrest; for others, its potential for control of the material world made it a destabilizing agent especially if proficients were drawn predominantly from one sector of a stratified society (Powell, 1832, pp. 197-8). Educational organizations of scientific knowledge were constructed for a plurality of social purposes and a contextual commitment to individualism, voluntarism and self-help enabled a rich variety of textual and institutional responses to emerge. In this period before the professionalization of science (Russell, 1983, pp. 220-34) and before the curriculum of state-supported schools had congealed, multiple 'science educations' were produced, reflective of diverse interests which adults displayed in knowledge of the natural world.

Yet despite its attractions and prevalence, this 'science for specific social purposes' (SSSP) did not become institutionalized in educational provisions as these were developed subsequently. Instead, schools and colleges, in so far as they incorporated science in the curriculum adopted a canonical version marked by abstraction and social disconnection. The complex political and intellectual negotiations which underpinned the eventual hegemony of academics, as opposed to 'practical men,' in the science community and the adoption of a common, as opposed to a diversified interest-related, science curriculum in schools have been analyzed elsewhere and are not recounted here (Layton, 1973; Layton, 1981; Bud and Roberts, 1984). A paradox of nineteenth century science education is worth emphasizing, however. As formal and state-supported provision increased over the century, scientific knowledge itself became progressively more removed from the public understanding. By the opening of the twentieth century laments were common about the failure of science to be assimilated into the common understanding. Science had succeeded in establishing a place for itself in education for the people, but, in doing so, had become insulated within the context of use. A major human activity had been rescheduled as a minority pursuit (Young, 1974, p. 58). In so far as the scientific community communicated with the public it was lagely on its own terms without regard to existing lay interests. Popularization, which in any case lay beyond the pale of scientific practice, was equated with dilution (Whitley, 1986, p. 3); public involvement in science, to the extent that it occurred, meant socialization into the perceptions of scientists and their ways of interpreting the natural world. In short, science for specific social purposes was replaced by science for science's sake.

The Learning of Science by Adults Today

The limitations of large population survey methods employing pencil-and-paper tests (Holmes and Wright, 1980) and/or telephone interviews (Miller, 1986) to measure public understanding of science and technology as well known (Prewitt, 1982, 1983; Layton, Davey and Jenkins, 1986). Some obvious difficulties are:

(i) Topics selected by scientists (insiders) as important may not correspond with topics so regarded by non-scientists (outsiders). If the former topics are the basis for test items, much scientific knowledge possessed by adults may remain unmeasured.

(ii) The salience of scientific topics selected as the basis for test items/interview questions may vary appreciably across the respondents. (Those living close to a site designated for the disposal of nuclear waste may be expected to score higher on questions about nuclear energy than those living in a nuclear free safe zone.) Salience, rather than understanding, may be what is being measured.

(iii) To ask survey participants 'whether they felt that they had a clear understanding of, a general sense of, or little understanding of' a technical term such as radiation, or how a telephone works (Miller, 1986, p. 8) leaves open the question of what is being measured: public understanding of science or the public's assessment of its own understanding? If the latter, the question arises of whether survey respondents are using a common measuring stick. Does 'understanding how a telephone works' mean the same to a physicist, a motor-car salesman and a supermarket check-out operator?

Evidence which seems to suggest the existence of a scientifically illiterate public may perhaps be better interpreted as indicative of a public which is non-conforming to the stereotype of scientific literacy as perceived by 'insider' scientists. Measuring the public's understanding of science is not the same as ascertaining the extent to which the public shares the scientists' view of the natural world.

Two general points arise from this brief critique of methods previously used to ascertain 'public understanding of science.' First, in considering adult scientific literacy, 'market segmentation' of 'the public' is essential. This can take place on a number of dimensions. In connection with science policy issues, Almond's (1950) stratified model (Fig. 1), adapted by Miller (1983, p. 25), 'reflects the differential ability of individuals . . . to devote the necessary resources, especially time, to become and remain informed and active.' In addition to this, however, there will also be 'issue specialization' because individuals differ in their selection of science and society issues to which they are prepared to devote time and effort. What follows from this is the recognition that measurement of adult scientific literacy is likely to be most useful when it relates to a specific segment of the adult population facing a specific issue. Examples are: members of Parliament debating the implications of in vitro embryological techniques (House of Commons, 1985); first-time parents taking decisions about infant nutrition (Morgan, 1984);

householders managing their domestic energy consumption (Bartram et al., 1985). A general index of public understanding of science would be of little value in indicating the sources of ignorance and confusion in each case, and in providing pointers to the kinds of educational provisions needed to bring about improvements.

Second, the 'outsider/insider' mismatch which Ziman identifies is not a product of lay caprice, stupidity or lack of understanding. It results from the fact that individuals exist not as rational isolates, but as members of social groups. They are subject to both individual and social value preferences which influence powerfully the ways in which they integrate scientific ideas into the grain of their everyday lives. The frames of reference they bring to bear upon scientific knowledge are both different from and more complicated than those employed by professional scientists in their work.

This point is well illustrated by studies on the behavioral and social aspects of energy consumption (Stern and Aronson, 1984). The energy of the political debates--of 'energy policy' and the 'energy crisis'--is not the physicists' energy, but rather a socially defined entity. Furthermore, there is no single socially shared concept of energy. As Stern and Aronson (1984, pp. 15-20) illustrate, it can be viewed with an emphasis on it as a commodity, an ecological resource, a social necessity or a strategic material.

As for the domestic 'energy user,' at least five perspectives can be identified (pp. 59-65):

(i) the energy user as investor who sees the purchase of energy equipment in the home as an investment which will increase the re-sale value. As with the purchase of other commodities, however, additional considerations such as safety, styling and status intrude.

(ii) the energy user as consumer who regards energy expenditure as providing necessities, comfort and pleasure.

(iii) the energy user as member of a social group the norms of which influence decisions. A homeowner may know that plastic sheeting over the windows will reduce heat losses but s/he will not use it because it 'lets the neighbourhood down.'

(iv) the energy user as expresser of personal values. Energy is used in ways which are consistent with personal ideals or a self-image. Thus a spacious, air-conditioned house may be deemed appropriate to the owner's perception of his social position whilst the installation of solar panels may be reflective of values of environmental concern and self-reliance.

(v) the energy user as problem-avoider who is reluctant to disrupt established household routines and accept temporary inconvenience in order to improve energy-use patterns.

One of the implications of this analysis is very clear. The provision of energy information on its own and without regard for the particular circumstances of the energy user is unlikely to lead to changed behavior. More generally, if science is to assist adults to empowerment in relation to real-life tasks and problems, it must be accessible in ways which respect the priorities and meanings which adults have constructed from their life experiences.

Case Studies of Science in Specific Social Contexts

Drawing upon the perspectives outlined in the previous sections, a project was begun in 1984 in the University of Leeds with the following aims:

(i) to explore the perceived needs of specific groups of adults for scientific knowledge in order to cope with a problem which confronted them;

(ii) to investigate the extent to which the adults were in possession of scientific knowledge relevant to their problem, and the sources from which they had acquired it;

(iii) to review the institutional provisions for the access to scientific knowledge by adults and to suggest new and innovative ways in which they might achieve empowerment with the aid of science, as appropriate.

Theoretical and practical considerations led to the selection of particular contexts for the investigation:

(a) Public domain context: decision-taking on a science/technology/society issue; local government elected representatives faced with a problem involving the disposal of toxic waste.

(b) Domestic context: coping with personal tragedy: parents of children suffering from Down's syndrome.

(c) Domestic context: material hardship: elderly people living on their own and the ways in which they constructed their domestic energy policy (i.e. keeping warm; obtaining hot water for washing and cooling; etc.).

(d) Work context: electrical tradesmen who install electric circuits for the supply of light and power in buildings: how do they conceptualize their work tasks and what 'science' do they use?

In each of these four case studies accounts of the meaning and understanding of the problem were constructed from the results of extended individual interviews in which the adults were allowed to talk about their problem, not as an event in isolation, but as an experience suffused with considerations intrinsic to the social and cultural context in which they lived. Such naturalistic modes of inquiry, designed to retain the integrity of the phenomena (Douglas, 1971, p. 16) are essential in order to achieve an empathetic understanding of how the adults perceive their problem, and how they interpret their need for further scientific knowledge. A brief account of the results of the interviews with the parents of Down's children will serve to indicate the direction of the findings.

Almost without exception, parents reported that they had received 'scientific' information about their 'problem' from medical general practitioners, pediatricians, genetic counsellors and others. Matter such as the chromosomal cause of Down's syndrome, the physical and mental manifestations of the handicap, and the risk of a further child being similarly afflicted were commonly mentioned. Almost without exception, and irrespective of educational background, parents had rejected this knowledge as irrelevant to the problem of coping with their domestic tragedy.

On the cause of the handicap, what science had to offer was an account of trisomy 21 (an extra chromosome 21) in standard, mosaic or translocation form. It was clear from the interviews that even those parents who held formal qualifications in science had limited understanding of what a chromosome was and did. Understanding aside, the value of this knowledge was unclear. As one mother expressed it, "Well, they just said that we've got 46 cells and they've got 47 . . . but really they didn't say how it comes by and, you know, things like that." Nor was there any satisfying explanation of why three of chromosome 21 should lead to the specific mental, anatomical and physiological symptoms of her Down's child.

What science appeared to be offering to the parents was knowledge which contributed, though as yet only partially, to an explanation of the cause and manifestations of Down's syndrome. It was knowledge that had been generated out of a long-term quest for fundamental understanding and also out of attempts to pre-natal detection and control of the incidence of Down's syndrome. What parents needed and sought was knowledge which assisted them to cope with a present child in the here and now; their time perspective was one of immediate application and their requirement was that knowledge should lead to action and improved performance.

Parental reaction to information about 'risk' was similarly dismissive. Interpretation of probability statements such as, "You have a 1 in 800 chance of having a child with Down's syndrome" was a source of difficulty, and distress, to many parents. For some the emphasis on a low percentage figure for Down's syndrome births served to emphasize their 'bad luck' in having a handicapped child. For others, it was an obscene reduction of a human tragedy to disembodied numbers. As one mother remonstrated, "We were sick of percentages, weren't we?" Some parents regarded the information as irrelevant because of the possibility of amniocentesis, though few of these seemed aware that one risk had merely been replaced by another. What emerges strongly from the interview data on this topic is confirmation that risk is a value-laden, rather than a merely technical, concept. Considerations such as the psychological need of a young mother to prove she can give birth to a 'normal' child or the perceived need by parents to helpt their Down's child by the stimulation which a brother or sister would provide appeared to be the prime determinants of the acceptability of the risk rather than any mathematical interpretation of probability data.

After rejection of most of what formal science had to offer, the parents' response was two-fold. Often they turned to voluntary associations which had built up a body of practical knowledge about coping with a Down's child. It was here, rather than in discussions with 'scientific experts' that many misconceptions were exposed and dispelled. Some parents, for example, believed that 'a Down's baby is a sick baby, and sick babies need a lot of sleep,' a notion in conflict with the advice that because Down's babies tend to sleep too much, they need to be woken and given sensory stimulation to accelerate motor development in the early months of life. Alternatively, or additionally, parents constructed their own 'practitioner knowledge' grounded in the intimate, day-to-day struggle to cope. Parents spoke of 'self-education' from their experiences. The father of a 26-year-old Down's son recalled his first recognition of his son's intelligence when he noted him, as a small boy, making undirected use of oven gloves to remove ice cubes from a freezer. "This child is not so dim," he concluded. "There are many other things we can teach him." Several parents spoke of Down's children as "infinitely teachable." "It's incredible what they can learn if they are taught." From their work with parents' groups, others had drawn conclusions about the extent of variability of manifestations of the syndrome, "as great as the variability of characteristics in the 'normal' population."

To categorize the 'practitioner knowledge' generated by parents as 'fold science' (Krimsky, 1984) might be misleading, but the interview data provide impressive evidence of the development of coping strategies which were clearly successful in realizing the potential of Down's children. It is difficult to avoid the conclusion that 'scientific experts' might learn something by listening to coping parents and acknowledging that their formulation of the problem, and their solutions have a validity which should not be ignored.

Institutional Implications

The argument in this paper points to the need for new institutional provisions for giving the public access to scientific knowledge. Some indication of possibilities is provided by the Science Shops (Wetenschapswinkels) of the Netherlands (Van der Linde et al., 1982) and the Public Service Science Centres, funded between 1977 and 1981 by the National Science Foundation in the U.S.A. (Hollander, 1984).

In the former, science was available as a commodity to be purchased 'over the counter.' A customer brought a question or problem and the shopkeeper, as knowledge broker, identified a scientist or science student, in a university or elsewhere, able and willing to provide an answer. In many cases an immediate reply was possible, but around 20% of the questions exposed gaps in existing knowledge and gave rise to research projects. The knowledge needed had not yet been constructed and often did not feature with any priority, if at all, on the agendas of professional science.

In the Public Service Science Centres much of the work, though by no means all, arose from the interests and problems of disadvantaged populations, minorities and the poor. The withdrawal of public funding for the Centres raised in sharp form the question of resources to support the functional science being constructed. A further question of central importance, arising from the involvement of the public in determination of the direction of scientific activity, is whether this represents a threat to the quality and integrity of research (Nelken, 1984, p. 5). In its extreme form this concern anticipates 'the de-institutionalization of the scientific profession'; "will science for the people . . . become also science by the people?" Weingart asks (1982, p. 55), and "could that work?"

In conclusion, the broad argument of this paper can be summarized as follows:

(i) there are compelling reasons why ways should be sought to increase public understanding of science;

(ii) both the record of history and what we know about adult learning of science today point to the same conclusion; if science is to be returned to the people to assist their empowerment in relation to problems with a science and technology dimension, then it will need to be structured in ways that relate to the interests of specific groups of adults (SSSP):

(iii) the acquisition of such functional scientific literacies will entail institutional provisions of novel kinds and will oblige "a reconsideration of the tensions between the needs, methods and values of scientists and citizens" (Chavis, Stucky and Wandersman, 1983, p. 424).

The problems of so "giving science away" (to adapt George Miller's phrase) (Miller, 1969, p. 1063) should not be underestimated. Without some equitable system of funding for different social groups, provision would merely reflect and augment the existing distribution of resources and power. It would seem as unacceptable to locate adult science education in the domain of free market forces (i.e. only those who can pay for it, receive it) as to place school science education there.

The role of 'teacher of science,' in the context of SSSP, would clearly require re-definition. The ability to identify, clarify and respond to the concerns of specific adult groups would be important, as would be skills in communiating with and mobilizing members of a scientific community whose value orientation may be perceived as under threat by association with citizen interests. As for scientists themselves, to the role of investigator that of interpreter of science would have to be added. On this point the Royal Society's report is explicit that "Scientists must learn to communicate with the public" (1984, p. 24); but communiation which fails to take into account the interests and needs of the audience is unlikely to be heeded.

There are also implications for school science which would need to be faced. What kind of school science education would be the best preparation for later involvement in SSSP? Are any of the arguments for SSSP at adult level equally valid in relation to the learning of science in schools, and, if so, what consequences do they have for the content, organization and pedagogy of school science? And if "the end for which knowledge was sought . . . by the learned, and the end for which it is requied by the multitude, are not the same but different ends" (Wilkinson, 1847, p. 3), what is the case for taking children into realms of explanatory theory which is over-elaborate for the solution of problems in most real-life contexts they will encounter (Driver, 1986, p. 455)?

It is not without significance that 'epidemic' and 'democratic' have a common root (demos = people). If, as the Royal Society asserts, Science is for Everybody, and if the thirst for science is ever again to become epidemic (Hindley, 1825), then a democratization of science education which takes a greater account of the interests and needs of specific social groups would seem essential.

References

Almond, G. The American People and Foreign Policy, Harcourt, Brace and Company, New York (1950).

Anon. The Philosophy of Mind, The London Magazine, 3rd Series, Vol. 1, p. 130 (1828).

Bartram, D., C.M. Crawshaw, D.I. Williams, A.J.E. Crawshaw and P.A. Lindley. The use of heating controls. Report: ERG/Y6543/85/1, Ergonomics Research Group, University of Hull (1985).

Bud, R.F., and G.K. Roberts. Science versus practice. Chemistry in Victorian Britain, Manchester University Press, Manchester (1984).

Chavis, D.M., P.E. Stucky and A. Wandersman. Returning basic research to the community. A relationship between scientist and citizen, American Psychologist, Vol. 38, pp. 424-434 (1983).

Douglas, J. Understanding everyday life, Routledge and Kegan Paul, London (1971).

Driver, R., and B. Bell. Students' thinking and the learning of science: a constructivist view, The School Science Review, Vol. 67, No. 240, pp. 443-456 (1986).

Hindley, C. An address delivered at the establishment of the Mechanics' Institution, Ashton-under-Lyme, June 22, 1825, Edinburgh Review, Vol. 42, p. 499 (1825).

Hinton, D. Popular science in England, 1980-1870, unpublished Ph.D. Thesis, University of Bath (1980).

Hollander, Rachelle. Institutionalizing public service science: its perils and promise, in: J.C. Petersen (Ed.), Citizen participation in science policy, Univeristy of Massachusetts Press, Amherst, pp. 75-95 (1984).

Holmes, B.J., and D. Wright. What do young adults know about science? Some results from two national assessments, National Assessment of Education Progress, Paper No. 08-5-50, Denver, Colorado (1980).

House of Commons. Hansard, Issue No. 1336 (11.02.85-12.02.85), Col. 641-706 (1985); Hansard, Issue No. 1346 (29.04.85-3.05.85), Col. 576-595, London H.M.S.O. (1985); Standing Committee D. Unborn Children (Protection) Bill, Five sittings (6.03.85-20.03.85), Hutchinson, London (1985).

Krimsky, S. Epistemic considerations of the value of folk-wisdom in science and technology, Policy Studies Review, Vol. 3(2), pp. 246-262 (1984).

Layton, D., A. Davey and E. Jenkins. Science for specific social purposes (SSSP); perspectives on adult scientific literacy, Studies in Science Education, Allen and Unwin, London (1986).

Layton, D. Science for the people. The origins of the school science curriculum in England, Allen and Unwin, London (1973).

Layton, D. The schooling of science in England, 1854-1939, in: R. MacLeod and P. Collins (Eds.), The Parliament of Science. The British Association for the Advancement of Science 1831-1931, Science Reviews Ltd., Northwood (1981).

Miller, G.A. Psychology as a means of promoting human welfare, American Psychologist, Vol. 24, pp. 1063-1075 (1969).

Miller, J.D. The American Public and Science Policy, Pergamon Press, New York and Oxford (1973).

Miller, J.D. Technological Literacy: some concepts and measures, unpublished paper, delivered at the National Technological Literacy Conference, Baltimore (14 February 1986).

Morgan, J. Effect of antenatal education on expectant parents' knowledge and attitudes regarding infant nutrition, Health Education Journal, 43(4), pp. 104-107 (1984).

Nelkin, Dorothy. Science as intellectual property. Who controls research? Collier Macmillan Publishers, London (1984).

Powell, Baden. Quarterly Journal of Education, Vol. 4, pp. 197-8 (1832).

Prewitt, K. The public and science policy, Science, Technology and Human Values, 7(39), pp. 5-14 (1982).

Royal Society. The Public Understanding of Science, The Royal Society, London (1985).

Russell, C. Science and social change, Macmillan, London (1983).

Simon, B. The radical tradition in education in Britain, Laurence and Wishart, London (1972).

Stern, P.C., and E. Aronson (Eds.). Energy use: the human dimension, W.H. Freeman, New York (1984).

Thackray, A. Natural knowledge in cultural context: the Manchester model, The American Historical Review, Vol. 79, pp. 672-709 (1974).

Van der Linde, A., B. Van der Lugt and J. Weerdenburg. Science over the counter: politicizing science? In: Risk and participation. Conference papers. Second conference on science, society and education, published by: Buro Stadium Generale, State University Utrecht, Maliebaan 103, 3381 CH Utrecht (1982).

Weingart, P. The social assessment of science or the de-institutionalization of the scientific profession, Science, Technology and Human Values, Vol. 7, No. 28, pp. 53-55 (1982).

Whitley, R. Knowledge producers and knowledge acquirers, in: T. Shinn and R. Whitley (Eds.), Expository science: forms and function of popularisation, D. Reidel Publishing Company, Dordrecht, Boston, Lancaster (1985).

Wiener, J.H. Radicalism and freethought in nineteenth-century England, Greenwood Press, London (1983).

Wilkinson, L.J.J. Garth. Science for all, London (1847).

Williams, G.A. Rowland Detrosier, Borthwick Institute of Historical Research, University of York (1965).

Young, M.F.D. Notes for a sociology fo science education, Studies in Science Education, Vol. 1, pp. 51-60 (1974).

Ziman, J. An introduction to science studies: the philosophical and social aspects of science and technology, Cambridge University Press, Cambridge (1984).

DAVID LAYTON is a Professor in the Center for Studies in Science and Mathematics Education, University of Leeds, Leeds LS2 9JT, U.K.

Bull. Sci. Tech. Soc., Vol. 6, pp. 219-221, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

ON THE FOUNDATIONS OF SCIENCE AND TECHNOLOGY STUDIES

Langdon Winner

When I learned that the topic for consideration in this symposium was to be "The Foundations of STS," I thought to myself, "That's easy enough: there's the Sloan Foundation, the Rockefeller Foundation, Exxon Foundation, Carnegie Foundation, National Science Foundation, and so forth." Of course the organizers of the Conference on Technological Literacy had something different in mind. They expected this panel would evaluate the intellectual foundations of science and technology studies, rather than its funding souces. Indeed, that is an important issue. But is is also worth noting that during the past twenty years millions of dollars from public and private foundations have been spent on academic STS programs around the country. Now is a good time to ask: To what end was this money invested? And to what effect? Given the fact that the content of socially produced knowledge often bears a positive relationship to its financial sponsorship, and given the fact that STS scholars study precisely such relationships in other domains, these questions are relevant to the epistemological task at hand.

An obvious answer, one prominently displayed in foundation grant applications, is that STS programs seem to extend and deepen the study of science and technology in their broader cultural contexts. It sounds just marvelous. In this view, STS research and teaching is devoted to making an improved understanding available to students, policy makers and the general public. If that were all there were to it, this flurry of activity would certainly deserve everyone's applause.

But, clearly, something else is happening as well. To a certain extent one role that STS programs have served, explicitly or implicitly, is to answer the tide of public criticism of scientific technology that has arisen during the past two decades. In this light, scholarly work may be understood as a way to blunt or co-opt what might otherwise be effective social protest by turning the topic into an academic specialty rather than a democratic movement. David Dickson's The New Science of Politics documents some aspects of precisely this push as it affected programs within The National Science Foundation. As a personal matter, I recall that as a member of an NSF-EVIST panel reviewing research proposals in the early 1980s, our day began with a brief talk from an NSF program administrator who explained that the program on Ethics and Values in Science and Technology was seen by top NSF decision makers as a way to absorb and neutralize public cirticisms of the scientific community. I was shocked to hear the matter stated so boldly. Evidently, the purpose of science and technology studies at that level is to be able to say to Congressmen and other persons concerned about social problems in this area, "Yes, we have somebody studying that."

In a similar way, some of the STS programs started during the past fifteen years were part of an attempt to restore our society's grateful appreciation for science and a commitment to uncritically received technological change. Such programs, including one that I taught in, could well be called HSTS programs--Hooray for Science Technology and Society. Their implicit motto is, "Better Understanding for Business as Usual."

At the same time there are a good number of STS scholars inspired by a different mission. They seek to change the prevailing, one-sided views of scientific and technical practice and to achieve a more critical, open-ended sense of what modern society calls "progress." They deliberately challenge the hegemony that combines left-brain ideas with right wing politics. Often it seems to me that this effort is a losing cause. In fact, the battle may already be over. Those of us who persist may be like the Japanese soldiers stranded in the jungle of some South Pacific Island decades after the end of World War II who rush out, bayonettes fixed, to attack a tourist luau.

Nevertheless, for those who persist, the question of the methodological foundations of STS is still of genuine interest. A maxim by Jorge Louis Borges describes the prevailing situation: "Every author creates his own tradition." In social studies of science and technology, each significant piece of work draws upon what it needs to make its statement. The possibilities are enormous and for good reason. This field of inquiry occupies an enormous void, one created by a society that long ago committed itself to forge ahead full bore with scientific and technical advance, but never to forge ahead in developing the critical self-reflection such change seems to require. Trying to fill that void, we sometimes find ourselves spread too thin. Thus, the idea of bringing together science and technology under a single rubric is a source of many misconceptions. While the two domains are obviously related in many ways, science and technology are distinctly different kinds of activity. It seems to me helpful to consider them separately at the outset and search for connections later on. Since my own work deals almost exclusively with technology, I will confine my observations to that.

During the past twenty years the available literature on the human dimensions of technology has expanded greatly. The writings of historians, philosophers and social scientists has produced an enormous body of material. We now have comprehensive theories about technology and human experience, detailed histories of specific inventions and innovations, numerous analyses of policy making processes involved in technological choice, and discussions of a wide range of issues about how technological applications affect the way people live. The methodological grounds for this work differ according to both discipline and topic chosen.

In the history of technology there has been a considerable, although by no means uniform, movement toward a consensus about how such history ought to be done. New tools, techniques and systems need to be studied for specific characteristics in their design, but also seen in the context of the social, economic and institutional conditions in which they arise. The best fruits of this commitment to a "contextual approach" are not yet available. Historians of technology still primarily talk to each other about internalist concerns. At this point we lack even something as basic as a useful one volume social history of American technology.

Political science has made fewer strides. There are occasional studies that explain the political dimensions of technological choice within a framework of bureaucratic or interest group politics. But there is no overall consensus about the purposes or approaches that a political science of technology might take. By and large political scientists still believe that politics is something to be found in Congress, the White House and national elections and that technology has no politics in its own right. Those, like myself, who take a different view toil as independent freeholders on the periphery.

Philosophy of technology shows a somewhat greater level of involvement at present. A good many philosophers from various schools of thought--analytical, phenomenological, Marxist, and others--have begun to address the significance of technology for questions in epistemology, metaphysics, ethics, aesthetics, and politics. Unlike the situation that prevails in philosophy of science, however, there is as yet little agreement about which philosophical questions here are the important ones. And are academic philosophers the only persons qualified to discuss them or do engineers, social scientists or others without philosophy Ph.D.s have something important to add? The Society for Philosophy and Technology now worries about these matters, trying to decide how broad (amorphous?) and rigorous (rigid?) the field will be.

It appears, then, that only one of the three disciplines with which I'm concerned has gone very far in refining its foundations of STS inquiry. That would be distressing were it not for the fact that during the past quarter century many of the most original and challenging contributions to this area of research have come from entirely unexpected, non-disciplinary sources. Much more unsettling is the fact that the best work has not penetrated public understanding or altered significantly the terms of public debate. We live in a time of remythification of science and technology in which critical understanding is bypassed in favor of blind faith.

LANGDON WINNER is Associate Professor of Political Science in the School of Humanities and Social Sciences, Rensselaer Polytechnic Institute, Troy, NY 12180-3590.

Bull. Sci. Tech. Soc., Vol. 6, pp. 222-228, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

TECHNOLOGICAL LITERACY AND THE UNIVERSITY: CONCEPTS, PRIORITIES, AND POLITICAL REALITIES

Joseph Haberer

I. Concepts, Definitions and Priorities

When the clarion call for "technological literacy" is sounded--and I take it that this conference is part of that call--what is it we are after? How clearly have we delineated the purposes of such an undertaking? How well have we thought through the concept of "technological literacy"? And what are to be the guidelines for the emerging mission to make Americans less technologically illiterate, or to put it in more positive terms, to enhance the level of technological literacy in America. My perception is (and in this I may be mistaken) that the largely unspoken assumption is that our concern is not so much with the more universal problem of literacy, and specifically technological literacy, but with its specific manifestation in the United States. And this, I will suggest means that in our country we have begun to put together an agenda that is relatively narrow in its conceptual orientation and in its programatic intent.

Technological literacy means being literate about technology. The problem associated with the phenomenon of technological illiteracy are then a subgroup that comes under the larger rubric of literacy itself. It seems to me appropriate then to begin by addressing our concerns with some clarification of the term "literacy." What do we mean by the concept? According to the Random House Dictionary of the English Language it is firstly, "the quality or state of being literate, especially the ability to read and write." It is also, secondly, "the possession of education."[1] In a nutshell there is a narrow and a broad definition. In the narrow sense, literacy is having mastered the skill that enables us to read and write. At the simplest level this means having broken the code of written language, namely knowing the alphabet, and having it within our power to master the literature of a field, and to communicate in a written form about it. At the most elementary level it also means that citizens can read signs, advertisements, blueprints, write checks, fill out questionnaires, and do sums. The context in which literacy arises is with the invention of writing in a culture, and takes place where "the society contains a class, a caste, or an occupational group whose members keep accounts, preserve religious and moral precepts in written form or use writings for some other specific purpose." In a modern contxt literacy is usually contrasted to illiteracy and focuses on the extent to which the skills of reading and writing are disseminated among the population of a given society. In a literate society it is presumed that most of its citizens can at least read and write a simple message.[2] As a UNESCO study summarized it "A person is literate who can, with understanding, both read and write a short simple statement on his everyday life."[3]

Breaking the code, however, is not enough and we would consider it essential that the competency reach a sufficiently high level to serve the needs of a modern, industrialized society, such as ours. The level of competency in the reading and writing of the language is a matter open for varying interpretations. Merely to be able to read and write at the simplest level is not enough, and makes one functionally illiterate. For example, I am functionally illiterate in Hebrew, even though I can read the language, at least its biblical and prayerbook version. I know some words, and some sentences: But I cannot read for meaning and I cannot write to communicate in it, even though I can copy the alphabet. Even if I spoke Hebrew fluently, but could neither read nor write in it, I would be illiterate. (My wife happens to be in that situation for both Hebrew and Arabic.)

In any case, mastery of the 3 R's (reading, writing and arithmetic) is the keystone to literacy in our society. The importance of obtaining a sufficiently high level of mastery is obvious enough: without that, we have functional illiteracy, which is in a modern context a crippling element for those persons or groups who have not mastered the basic skills. What is central to this first definition is the instrumental value attached to it. Skill is the essence of this type of literacy.

The broader meaning revolves around the notion of being educated. Educated means having mastered, being familiar and feeling comfortable with the literatures and the world of knowledge that is the hallmark of an educated person. Presumably there are commonalities in a given society, some knowledge and learning that all are expected to share. Beyond that, education (as distinct from training) esconces the world of civilized discourse: in art, science, learning--the languages and literatures that are the medium of written communication about these enterprises. This broader meaning of literacy has an intrinsic value attached to it. In principle at least--to the extent that we do not confuse training with education--education carries within itself a civilizing function (of which literacy is an essential component). Education is recognized as a good in itself, or as an enabling good (for example, a necessary condition to make possible a democratic polity). Only secondarily is it viewed on as having instrumental value and least important as having a pecuniary value. The primary stress in the broader definition of literacy is on the inherent value of learning and knowledge.

I have gone into this somewhat belabored definitional approach because it is important to recognize that depending on which of these two meanings we stress--in words and in deeds--two different kinds of goals (ends) and policies (means) will follow. Our conceptual underpinnings will in fact shape our policies as well as our priorities--and therefore, we would be wise to think carefully about our meanings, and to bring our assumptions to the surface.

II. Technological Literacy and the Modern State

When I was asked to take part in this panel I was both pleased and bothered. Pleased because it gave me a chance to think about what is becoming a major concern among educational and science/technology policy makers. Bothered because (without false modesty) I consider myself not especially well equipped to address this problem of technological illiteracy--that is, I'm not an expert on it. Moreover, in all honesty, I feel myself in many respects technologically illiterate. If I gave you a list of the technological aspects in the world in which I live about which I am in near total ignorance, that list would be quite large. This no doubt is deplorable and a widely shared condition among "educated" persons. Pondering on the extent of technological illiteracy, I was reminded of what Max Weber, the German sociologist, wrote in the early 1920's in his famous essay, "Science as a Vocation." Let me quote a rather lengthy passage, for the point he makes in it is significant:

> *Scientific progress is a fraction, the most important fraction of the process of intellectualization which we have been undergoing for thousands of years and which nowadays is usually judged in such a negative way. Let us first clarify what this intellectualist rationalization, created by science and scientifically oriented technology means practically.*
>
> *Does it mean that we, today, for instance, everyone sitting in this hall, have a greater knowledge for the conditions of life under which we exist than has an American Indian or a Hottentot? Hardly. Unless he is a physicist, one who rides on the streetcar has no idea how the car happened to get into motion. And he does not need to know. He is satisfied that he may "count" on the behavior of the streetcar, and he orients his conduct according to this expectation; but he knows nothing about what it takes to produce such a car so*

> *that it can move. The savage knows incomparably more about his tools. When we spend money today I bet that even if there are colleagues of political economy here in the hall, almost every one of them will hold a different answer in readiness to the question: how does it happen that one can buy something for money--sometimes more and sometimes less? The savage knows what he does in order to get his daily food and which institutions serve him in his pursuit. The increasing intellectualization and rationalization do not, therefore, indicate an increased and general knowledge of the conditions under which one lives.*
>
> *It means something else, namely, the knowledge or belief that if one but wishes one could learn it any time. Hence, it means that in principle there are no mysterious incalculable forces that come into play, but rather that one can, in principle, master all things by calculation. One need no longer have recourse to magical means in order to master or implore the spirits, as did the savage, for whom such mysterious powers existed. Technical means and calculations perform this service . . . ."* [4]

I take it that for Weber the fact that citizens are for the most part technologically illiterate is in itself not so much a major problem as a given. Our modern condition, after all, is based on a massive division of labor, and intensive and extensive specialization. Surely, we do not expect, any of us, to understand or master the basic knowledge of the technological elements in our technological society. Under the best of conditions there are likely to be large parts of our technological environment of which we will be in ignorance: a scarcity of time, energy, commitment see to that; other interests and priorities will limit the effort given to the understand of technology. The point is: as Weber suggests, we know, most of us, anyway, that if we were to give enough attention to the matter, we could understand, we could master it. Most of the time it is enough that we recognize that the technology is understood (in its technical manifestations) by others--the technologists (experts) who have competency in it, and the laypeople, who have given time and energy to comprehending it, for example, policy-makers. I would not want to claim that this is as it should be--merely that this is our present condition, and that most of us are satisfied with it. I doubt that the mandate under which a "technological literacy" campaign is undertaken will have that broader kind of generalized understanding of technology in mind. Are we really bothered by the fact that the proverbial man or woman in the street is ignorant of so much of the technological terrain?

I put it to you that the primary concern of the emerging technological literacy campaign is programatically quite narrow and pragmatic. What is that we (that is those that shape, make and influence policy) are concerned about? Not lieracy as a general social problem or cultural good. Of course, in theory, it would be nice if more of our citizens were technologically or otherwise more literate, that is, better educated. But we are not, let us be honest about it, particularly incensed (in this case) over the studies that show high levels of ignorance. We make pious sounds, and continue, by and large, with business as usual.

What really is at issue here is a concern with national interests, national power, and national pride. The objective is to maintain or (in some cases) to regain a primacy in our technological (scientific) capabilities--or a fear that we may lose our earlier preeminence. This concern over our national position is centered on two arenas of public policy: the economic and the military.

We live in a period when economic well-being depends largely on our capability to compete effectively and efficiently in world markets, in which our competitors are themselves countries with sophisticated technological capabilities. If we fall behind in our technological innovativeness, in our ability to adapt and adopt technology in this competition for shares in the world-market (of which our domestic market is a part), we will, as it were, suffer the consequences. At issue is not only the fear of losing out, with the very tangible consequences that follow such a loss. There are more subtle aspects at work here: the psychological fear that we will become (as a nation) has-beens, number two, or (God forbid) number three! And even worse, if we don't put our shoulder to the wheel we will slide into the morass of backwardness: the American nightmare of becoming a loser haunts us.

Given the world in which we live, I am willing to admit that the concerns are real and need to be addressed. The underpinnings of a national resurgence, re-industrialization, the reassertion of or primacy does depend, in patr at least, on our technological capabilities. Technological literacy serves to create the conditions through which the cadres of experts can be found, trained, and equipped to fuel the drive for technological preeminence. In order to find and nurture the necessary talent, a wide net has to be spread: thus the emphasis upon strengthening all the parts of our educational system, from elementary school to the post-doctoral level. New curriculums will be tried, new programs will be started, new gimmicks will find their ways into school systems. Consultants, projects, proposals--all these will hone in on technological illiteracy, when the funds become available. Some attention will be given to the need to make citizens more appreciative, more knowledgeable of technology. Most of this will be at the level of symbolic reassurance--providing through symbolic gestures the sense that one is dealing with the heart of a problem, when one is in fact only putting it off, and allaying concern over it.[5] The technological literacy campaign does not now and most likely will not have as its goal the cultural objective of making our citizens more appreciative and knowledgeable (i.e. more education) about technology.

We have an analogue here in the response to Sputnick nearly three decades ago. There too we felt a challenge (threat) to our national pride and preeminence. Our scientific/technological superiority was called into question. We marshalled our resources to meet that threat, recognizing that there too scientific/technical literacy (higher levels of competence) were needed. Our schools--from elementary levels to the centers of higher learning--became part of a policy to catch up, and to regain primacy. The main purpose of that effort was not cultural, but political: to locate, to channel the scientific/technical brain-power and expertise towards the articulated ends. Raising the general level of scientific literacy among citizens was, I would argue, a secondary and, for the most part, a quite peripheral part of that response. Moreover, the programs to develop a broader citizen appreciation of science, probably lay in the recognition, that in the long run, support for the large scientific/technological undertakings was based on public opinion. This earlier multifaceted campaign succeeded brilliantly in its key objective. My point is that the goal was primarily instrumental, quite narrow, and failed in the larger, cultural goal of creating a broad-based scientific/technological literacy.

The other policy concern is the importance of technological capabilities in the area of military research and development: that is, the needs and imperatives of the arms race. We are now quite caught up on that escalator, and don't know how to get off it.

If what I am suggesting has validity, then I put it to you that it is important for us to rcognize that certain consequences follow from (a) our conceptual orientation--that is, whether we take a narrow, instrumental or a broader, cultural view of technological literacy; and (b) the direction of our energies into policies that are fixated on the economic/military needs of the country, or focus on the larger cultural and democratic dimensios that technological literacy may entail. If knowledge is power, then those who understand and control knowledge control policy. There are important issues here relating to democracy in the modern nation-state, that need to be addressed, but which I will not deal with here.[6]

We should, in any case, lay aside the illusion (or the hypocracy) that we have a larger, grander purpose in mind: the creation of enlightenment, the extension of human potentialities. I don't believe that is what our concern with technological literacy is about (though obviously I think we should focus much more on this aspect).

III. The University, Education, and Literacy

Let me make a few points about teaching at a university or college in the context of our concerns about technological literacy. The articulated purpose of education at the undergraduate level is two-fold: first, to educate; second, to train. The first addresses itself to the broader civilizing function of literacy to which I alluded to earlier. To be technologically literate, in this sense, is part of being educated. It means to understand and be able to communicate about technology at a general level. Technology is a vital part of our culture. Understanding that phenomena, appreciating its place in our culture, and being able to read, write and think about it should be an important part of what we call general education. Moreover, it is an essential element of effective citizenship, at least in a democratic political order. There are also more tangible benefits: the value of shared knowledge and experience: the commonalities that create a vital community.

In theory (if indeed there is a theory), the general education requirements at an institution such as the one at which I teach, are to fulfill this purpose. The curriculum, however, is so amorphous and flabby, that for the most part, students come out of the educational factory, often reasonably well-trained and competent in their specialized fields, but poorly educated. This means, in effect, that the second function dominates: we devote most of our energies, institutionally speaking, to the training of students for the professions, for jobs. We provide them with the required skills to function adequately at a variety of managerial, technical, scientific, organizational and personal positions.

To be sure, both these functions--the educative and the training function--have always been part of the university's task. What has changed over the last generation or two, at least as far as I can tell, is that while the educative function was once held to be essential and even primary--the purpose for going to college was to become educated--this seems to me to be less the case today. Vocationalism, professionalism have become the hallmark of our institutions of higher learning. Large universities like mine give the appearance of being educational factories--with very low levels of quality control in the area of general education and literacy. In practice (again based on my limited experience), this means most students who go through the factory, obtain a smorgasborad type of "education"--grounded on the diluted and often nebulous theory of education which undergirds it. Many, if not most of the students who graduate, are poorly educated by any criteria that one would want to apply. They certainly are not very literate; that is, they lack a mastery or knowledge, of literatures, in anything, except, perhaps, in their major field. In short, we pay lip service to education, while it atrophies.

Take the kind of courses I teach: "science and government"; "environmental politics and policy"; "science and culture"--about three quarters of the students in these courses come from the schools of engineering, science, and agriculture; the rest major in one of the social sciences. Occasionally there are some from history. In the last decade I have almost never had a student who comes from the humanistic disciplines: English, Foreign Languages and Literatures, etc. The two-culture syndrome is alive and well. Nearly all the students are juniors and seniors (even in the introductory courses). And most of them, while not functionally illiterate, do not know how to read and write well (and that is putting it kindly). Since there is such a direct connection between clear writing and clear thinking, you can understand why I believe that this situation points to a serious indictment of the educational system itself.

The problem is systematic. This failure is not due to the inadequacies of students. On the whole they are intelligent and full of promise, and potential (most of it, of course, unrealized). The humanities students are fearful of anything that smacks of science and technology; and the science/engineering students are leary of the social sciences and humanities; the faculties across the two divides view each other with suspicion and disdain. Few bridges are being built.

Let me get to the point: I think we should be talking about literacy, before we turn to technological literacy. I will put my major assumption on the table and simply assert that the beginning of wisdom, at least for me, is the recognition that the problem of technological literacy cannot be divorced from the problem of literacy itself.

Last week, while preparing this talk, I came across a passage in a book by one of the guardians of the plain English movement, The underground grammarian, Richard Mitchell, who in Less Than Words Can Say[7] writes:

> *At one time I thought I was the victim of a conspiracy myself. I was certain that the Admissions Office had salted my classes with carefully selected students, students who had no native tongue. Many of my students seem unable to express themselves in any language whatsoever. They aren't utterly mute, of course. They can say something about the weather and give instructions about how to get to the postoffice. They are able to recite numerous slogans, especially from television commecials and the lyrics of popular songs and recent--very recent--political campaigns. They are able to read traffic signs and many billboards and even some newspapers, and they can claim certain emotions with regard to various teams and even individual athletes, whose names they often know. They can spin more or less predictable reveries about the past or the future either in very simple concrete terms or in sentimental banalities, or both. But they cannot pursue a process; they cannot say when evidence leads to a conclusion; they cannot find examples for analogies; they've never heard of analogies. They speak and write English as though they were recent immigrants from Bulgaria, whose Bulgarian itself had been totally obliterated on Ellis Island.*
>
> *Of course, it was an illusion, a phantom of wishful thinking. There was no conspiracy at all. They were just ordinary American students pretty much like any others. They were the typical product of our schools.*

This passage struck a chord. There is, perhaps, an element of exaggeration; Mitchell may be excessive in his sardonic style. But, frankly, it is not much off the mark, if we take into account most of the "products" of our system of higher education. If, indeed, the system is failing to educate--at least most of its students--wherein lies the failure? And shouldn't we address ourselves to that question?[8]

It may be, as I have suggested, that the inner logic of the system is not to educate most of the students, but to locate the top performers and channel them into a kind of elite system. In a system of mass-education, both at the pre-college and college level--is it that we do not really believe in education for all? (Training, yes!) Or that the system is incapable as it is now set up of educating its citizens except in the narrow terms to which I referred. The implicit motto may be: functional literacy, yes! Education, no! Or, is it, that in a deeper sense we have no desire, no intent, no faith in mass-education. Is the intellectualist strain in tension with the democratic ethos? I believe that a strong argument can be made along some of these lines--but this conference is not the time or place for it.

Let me, however, state categorically my rejection of elitist premises. I believe that citizens are capable of being educated in the broader sense; that there are vast untapped potentials. The failure is one of vision and commitment. Nor do I believe that the major, core problem is one of means. I share Immanuel Kant's maxim: that so long as we are dealing in the realm of what is possible, if we will the end sufficiently, the means to bring about its achievement will also be willing into being.

In conclusion, technological literacy needs to be addressed in terms of a larger, systematic problem of literacy. To the extent that we clearly articulate our goals, and generate sufficient will to bring them about, the means to do so become an important, but secondary, problem. Our danger is that in a conference such as this, we focus on the problem of means, before we have cast the searchlight of critical inquiry on the prior task of deciding upon ends.

References

(1) Random House Dictioanry of the English Language: Unabridged Edition, 1966, p. 836.
(2) Hilda H. Golden, "Literacy" in International Encyclopedia of the Social Sciences, Volume 9, Macmillan, 1957, pp. 413ff.
(3) Quoted in Harvey J. Graff, The Literacy Myth, Academic Press, 1979, p. 3.
(4) From Max Weber: Essays in Sociology, translaed, edited and introduction by H.H. Gerth and C. Wright Mills, Oxford University Press, 1958, pp. 138-139.
(5) Jacob Murray Edelman, The Symbolic Uses of Politics, University of Illinois Press, 1964.
(6) David Dickson, The New Politics of Science, Pantheon, 1984.
(7) Richard Mitchell, Less than Words Can Say, pp. 156-157, Little Brown, 1979.
(8) Remedial work is being undertaken at some universities and colleges to deal with this problem among science and engineering students. See, for example, "Science and Math Professors Are Assigning Writing Drills to Focus Students' Thinking," by Liz McMillen in The Chronicle of Higher Education, January 19, 1986, pp. 19-20. Purdue University has assigned a full-time staff member in tis school of Chemical Engineering for similar purposes, to help not only students but faculty to write better.

JOSEPH HABERER is Associate Professor of Political Science at Purdue University, West Lafeyette, IN 47907. He is Book Editor of The Bulletin of Science, Technology & Society, and a member of the National Advisory Committee of the Science through Science, Technology & Society Program.

Bull. Sci. Tech. Soc., Vol. 6, pp. 229-234, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

TECHNOLOGICAL LITERACY, OLD AND NEW

Donald deB. Beaver

Abstract

As one of the Sloan Foundation's original New Liberal Arts grantees, Williams College has developed a variety of approaches to improve quantitative reasoning and technological literacy, including creating interdisciplinary courses, computer and mathematical workshops, and an STS program. Further development, however, depends critically on what technological literacy may mean in a liberal arts context. Attempts to promote technological literacy, whether in liberal arts settings or not, are likely to founder unless they take account of the complexity and context dependent nature of technological literacy, as well as its history, and its relationship to scientific literacy.

What is technological lieracy old or new, and what has Williams been doing to promote it?

Before discussing concepts of technological literacy and describing NLA activities at Williams, some brief background about the college should provide helpful context.

Williams College, founded in 1793, is a coeducational liberal arts college with about 2,000 undergraduate students, located in the northwestern corner of Massachusetts, in Williamstown, in the Berkshire Mountains. Williams' curriculum is 4-W-4; semesters are about 13 weeks long, and winter study in January is required, not optional. Academic departments are clustered in three divisions, the humanities, social sciences and natural sciences. In order to graduate from Williams, a student must have a major course of study (ca. 9-11 one-semester courses in one department), and must take at least two one-semester course from each of the three divisions. Such minimal distributional or general educational requirements mean, for example, that a student's total exposure to college-level education in science may come from mathematics or computer science alone.

About ten years ago, the Program on Science, Technology, and Society at Cornell Uniersity surveyed STS courses, research, and resources in the United States. At that time, Williams offered at least 14 STS-like courses, which meant that approximately half of each graduating class had had some experience with STS or scientific literacy type courses, in addition to the science requirement.[1]

That representation in the curriculum remained relatively steady over the past ten years, if anything, slightly increasing. Course offerings changed considerably, as faculty came and went, or shifted interests, but year after year some 20 to 25 courses, either science courses for non-science majors or courses related to STS concerns, were given. Of these, the largest enrollments came in the courses which also counted for distributional credit in the natural science.

Despite a common American liberal arts college tradition of strong departmental autonomy, which often militates against interdisciplinary and non-mainstream curricular offerings, Williams hired individuals with sufficient breadth that the sciences appeared as objects of study in great and continuing variety, not only in departments of natural science. Some of the cause for this policy undoubtedly derived from the Environmental Studies

Program, an interdisciplinary, interdepatmental program staffed by interested individuals from various departmental homes. In consequence, Williams has continued to enjoy a vital curricular base in support of education for understanding science for students majoring in the humanities and social sciences.[2]

Consequently, when the Sloan Foundation offered Williams the opportunity to apply for the New Liberal Arts Program, the college began from a rather strong position, insofar as scientific literacy is concerned. With regard to quantitative skills or technological literacy, however, considerable room for improvement existed, and, for the former category, already constituted some measure of concern. More than half the failing grades for first term midsemester freshmen came from the mathematical and natural sciences.

Williams decided to focus its NLA efforts on "faculty development," assuming that without some sizeable number of faculty members commited, experienced, and enthusiastic about quantitative literacy and/or technological literacy, little change would occur in students' educational experience.

The area of quantitative skills proved in some senses the easiest to cope with formally, and yet most elusive to define. The Mathematical Sciences Department thoroughly reviewed and revamped its curriculum in mathematics and computer science, and began a Mathematics Workshop for helping students in need. Two years later, a committee from the natural sciences developed a mathematical skills qualifying test to be administered to all freshmen; those scoring lowest on the test became ineligible for certain science, math, and computer courses normally open to freshmen, but known to be difficult for students with weak quantitative repertoires. Additionally, the mathematical sciences department sponsored several in-house faculty workshops on operating and using microcomputers. A number of faculty in the social sciences and humanities (especially in foreign languages), who previously had regarded computer technology with feelings slightly more negative than indifference, began to write and develop their own programs, both for themselves, and for use by students in their courses. Whether or not the student use of microcomputers constitutes a step toward either quantitative or technological literacy remains debatable--without context or specific description, it is impossible to judge.

For the New Liberal Arts Program in general, Williams developed a significant number of new course offerings, several of them team-taught. In addition, some courses were significantly modified in order to include units relevant to NLA concerns. A comprehensive listing of these courses, together with some others of the same type which had been developed and offered before Sloan Foundation support, appears in the May 1985 issue of the New Liberal Arts, pages 44-55.

Some of the more inventive and unusual courses involved collaborations between scientists and non-scientists, as, for example, in "Human and Artificial Intelligence," taught by a mathematician and a philosopher, and in "Nuclear War: History, Ethics, and the Environment," taught by professors of religion and biology. 1986-87 should see an offering by a team involving mathematics and theater, and a course in "Reproductive and Genetic Technologies," created by a philospher and a chemist.

In addition, courses in Philosophy and Technology, in Forensic Chemistry, in History of Science and Technology, and in Science and Technology Studies flesh out the NLA curriculum. Furthermore, for courses on industrialization in history, neurophysiology in psychology, and economic development, new interactive computer exercises have been developed and tried out.

These, added to the usual offerings from the sciences, and from the Environmental Studies and American Studies Programs, have produced a curriculum rather richer in quantitative studies and technology than before.

Finally, in the spring of 1985, the faculty voted to create an interdisciplinary Program in Science and Technology Studies, to consist of an inroductory course, a group of electives including laboratory or field experience, and a final research seminar. With courses in the history and philosophy of technology already in place to represent the humanities and the social sciences of technology, there remains only to develop a "natural sciences" course in technology to complete a solid foundation.

What is particularly strong about these developments is that many departments are represented, and many of the faculty involved are tenured, so that one can expect the curriculum to benefit from these kinds of offerings for some time to come. If anything, the Sloan Grant has intensified an already strong position at Williams, and begun to broaden that position in the direction of technological as opposed to scientific literacy.[3]

Williams had hoped to develop closer relations with Rensselaer Polytechnic Institute, so that both institutions might benefit from each other's strengths. Apart from beginning a student exchange program, however, and exchanging some visits and colloquia, not as much has developed in that area as hoped, in part because of the different rhythms of an engineering school with research laboratories, and a liberal arts college committed to excellence in teaching. It is clear, however, that Williams' Science and Technology Studies Program will benefit from the presence of an STS major and graduate degree program at RPI, and that STS provides a natural area for coordination and collaboration in activities between the two institutions.

Central to what remains to be done, however, is a rethinking of what the goal, "technological literacy," may mean in the context of a liberal arts education.

Perhaps the most obvious feature concerned with technological literacy is that no articulate description of technological literacy exists. Apparently nearly all concerned can recognize technological literacy when they see it, but can't sufficiently describe what they see so that others would agree, on the basis of the description alone, that technological literacy is being demonstrated.

There is nothing especially novel about such a state of affairs. Problematic "literacies" of many types have proliferated in recent years--quantitative literacy, scientific lieracy, computer literacy, and even agricultural literacy. At conference after conference, colleagues debate and argue the nature of the various literacies, in virtually the same terms as at the first Technological Literacy Conference in Baltimore, and to the same result: no resolution.

Is the lack of definition curable? Does it matter?

In the first place, so many different contexts exist within which to define technological literacy that without one agreed-on context, it is probably impossible to specify what technological literacy is. In the second place, in the context of a liberal arts education in the late twentieth century, it really doesn't much matter how one defines technological literacy, as long as the definition isn't too remote from some reality. Technological literacy, like the other literacies mentioned, may turn out to be a consequence of education in the liberal arts, but is remote from the mission of liberal arts education.

Despite their incidental production of well-informed and broadly educated citizens, liberal arts colleges' main goals are to aid people to cultivate a love of learning and an ability to learn independently. Ideally, liberal arts graduates will enjoy learning for the rest of their lives, and will have confidence that they can learn any subject, given interest, need, opportunity, and time.

Few liberal arts college graduates are "literate" in every subject taught at their institutions. They haven't had the time, and won't have the time to learn about everything of interest to them. They make choices (ideally, informed choices) about how best to invest their time and energy. Most people, however, don't make choices so freely; they have progressively limited their interests since childhood, through education and other experiences. For them, that is, for most of us, the idea of learning about some subjects provokes anxiety, stress, and lack of confidence. Consequently, many have surrendered their ability to choose to be literate.

If there is technological "illiteracy," it is for understandable social and historical reasons.

The literacies in which our society is supposedly so seriously deficient all share a common technical-scientific nature. Yet children in our society are fascinated by how and why things work, by living organisms and their interrelationships. Most adults are, too, but unlike children, many have learned to become anxious about understanding technical affairs, fearing that they are too "stupid" to really understand what only "brains" enjoy. So, they have become "illiterate," not from lack of innate interest, but from experience which has taught them to avoid those areas. There is nothing unusual about this; most humans are intensely curious, but learn to control their curiosity, finding out that limiting curiosity and interest can often be practical. In too many cases, however, self-imposed limitations, however immediately practical, become in the long term, crippling constraints.

But it is not just formal education and the esoteric nature of technical knowledge which help promote technical illiteracies. It is also, in many ways, the form and content of the diffusion and dissemination of technical ideas outside the schools. Examination of some of the problems of scientific literacy may help to shed light on the problem of technological literacy.

Despite the public's continuing high regard for science, many educators and most of those concerned with scientific literacy perceive the American public to be unknowledgeable, indifferent, and sometimes even hostile to science. Decreasing national enrollments in the sciences seem to bear out such characterizations. Yet the market for "scientific" popularization has scarcely ever been better. Television programs proliferate (Ascent of Man, Connections, Cosmos, NOVA, Newton's Apple, Planet Earth), magazines flourish (Omni, Discover, Science 86), and newspapers publish special science sections (New York Times, Boston Globe). The public is bombarded with technical information. Does the public pay any attention? Apparently not, for if it did, people wouldn't believe in so many unscientific ideas.

Perhaps, however, the public pays attention only too well, if one looks closely at what often passes for the popularization of science. The most frequently featured topics involve the "mysteries" of science or "Gee Whiz" phenomena which capture attention, much as do the entertaining commercials of television. So disconnected are the episodic fragments of popularization that they resemble little more than disembodied trivia, a technical "Believe it or Not," to be taken on faith as true, unless one dares to be considered unscientific. Thus has the distinction between science and religion become blurred. With science as the new faith, superstition (belief in authoritarian pronouncements about fragments of scientific "knowledge") once again becomes acceptable.[4] No wonder that astronomers in vain deplore public interest in astrology. After all, what criteria for choosing between superstitions have been popularized?[5] The authority of science scarcely qualifies as an unbiased, objective warrant of the validity and adequacy of science's claims.

No, if the general public is scientifically illiterate, it is rationally and appropriately so, considering the ways in which science has been presented to it. It appears that the same holds true for technology as well.

People have never been as interested in science, conceived of as explanations of natural phenomena, as in technology. For more than a century, scientists seeking public support have argued that all research eventually pays off in something useful, namely a technology. For their supporters, as for Francis Bacon, the true and legitimate goal of the sciences is "the endowment of human life with new riches." The scientists' argument continues to appeal; the general public's greatest interest in "science" is in new processes and products, namely, in technology.

Thus, given public interest in technology, factors other than the fragmentation of knowledge may have helped contribute to contemporary illiteracy. One factor connecting to science is the prevalent model, especially exemplified by "hi tech," that creativity flows from science to technology to consumer goods--and if one can't understand the science, there's little point in trying to understand its derivative technology.

In part, some technologies have become more opaque, less accessible to inspection, less easily comprehensible. Possible levels of understanding have multiplied, as has technological complexity. If one were to go back to colonial America, concern for technological literacy would seem strange. Even as late as the close of the heroic age of American invention, when Tom Swift was replacing Horatio Alger, the same might be claimed. But could a believable Swiss Family Robinson be written today? (Is Gilligan's Island an illuminating substitute?)

To complicate matters, knowledgeable experts disagree on many important questions involving technology today, e.g. acid rain, radiation, risk assessment. What then can it mean to have a public which is technologically literate, if those most intimately acquainted with technology can differ so fundamentally?

If, relative to the past, contemporary technology is more complex and diverse, it is time to recognize that its corresponding literacy has the same complexity of many levels and forms.

What really seems to concern are the possibilities of social fragmentation and loss of support for technology, of excessive dependency upon technically sophisticated others, of gullible and manipulable citizens, who, enslaved by their ignorance, enslave the society. Both technological optimists and technological pessimists share such feelings, but for different reasons. The technological pessimist fears that the natural state of humans in a complex technological society is dependency, because of one or another sort of technological determinism. The technological optimist fears that the dynamic source of vitality for a technological society is likely to be compromised or corrupted, if embedded in a populace increasingly indifferent, fearful, or ignorant of its true, liberating nature. Hence, both optimist and pessimist share the goal of technological literacy, although by it they mean very different things.

Hence, also derive the uneasy feelings about science and technology studies, about appraoches to technological literacy which don't involve hands-on experience and understanding of technology itself. In a particular and concrete situation of comprehending how something works, it is difficult to keep in mind the social, historical, political, and economic context of that technology. Thus, the satisfaction and confidence of coping with technology, that sense of internalized control and power, is likely to diffuse into a very positive attitude towards technology in general. In understanding technology apart from its full context, the resulting sort of technological literacy is insulated against pessimism. In most STS studies, however, complexity to interdependency are omnipresent, so that there is less probability of engineering a series of solely positive feedback experiences with technology. Indeed, if students have already had negative experiences with technology, such experiences may become material for reflection and analysis. In such cases, the resulting technological literacy, if more appreciative of complexity, is less likely to be one of unqualified technological optimism.

What then is "technological literacy" within the liberal arts tradition? With technological complexity and change compounding the problems of determining some standard context, defining technological literacy defies common solution. In the first approximation, however, liberal arts graduates should have the confidence that they can, if they choose, become independently well informed about any technology, and that furthermore, such learning is enjoyable and rewarding. If the liberal arts experience really produces a life-long love of learning, then that learning will include technology, because the ubiquitous presence of technology cannot be ignored and avoided. And, to the extent that ubiquitous technology appropriately appears throughout the liberal arts curriculum, that is, to the extent that faculty themselves are technologically literate, the problem of technological literacy disappears.

Footnotes

1. Eleven of the 14 courses carried humanities or social sciences credit, not natural sciences. With an average enrollment of about 20, approximately 220 students were involved, without overlap. That means about 44% of a graduating class had some experience with STS or scientific literacy courses beyond fulfilling the science requirement.

2. Despite the good record in course offerings, there exists no good estimate of how many students managed to avoid all study of science, except for the requied two one-semester courses. For one graduating class in the early 70's, some two-thirds of the students majoring in the humanities took no more than the required two one-semester courses in the sciences.

3. This is not to say that scientific and technological literacy are opposed, but they do represent two different, if similar, things. Some of the courses in "technological literacy" are little different from science for non-scientists courses, only adding technology as a hook to capture students' interests and motivate them to learn (endure learning about?) the science. In part such practice is unavoidable and necessary, but not stretching beyond the familiar to the unexplored and unstandardized regions of technology scarcely advances the cause of technological literacy.

4. This argument is beautifully elaborated in an as yet unpublished manuscript by Professor John Burke of Ohio State University. His work, an historical examination of the popularization of science in America, is tentatively titled How Superstition Won and Science Lost.

5. This was essentially one of the ponts made by Professor David Suzuki in his February 15 speech at the Technological Literacy Conference in Baltimore, when he pointed out that most of us justify our "knowledge" by "I saw" or "I read." He went on to point out that many people "read" the National Enquirer. If others read other sources, however, how do we settle differences of authority? Or do we care?

DONALD DeB. BEAVER is Professor of History of Science, Chairman of the Science and Technology Studies Program, and Director of the Sloan New Liberal Arts Committee at Williams College, Williamstown, MA 02167. His research interests lie chiefly in the social history of science and in scientometrics.

Bull. Sci. Tech. Soc., Vol. 6, pp. 235-239, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

THE LIBERAL ARTS IN A HIGH TECH SOCIETY

Carl Mitcham

"Liberal arts" is one of those ancient and honorable but sometimes misleading terms. In our high technology society, with a current student generation very much concerned about jobs and careers, it is also often honored only in the breach.

This is a mistake, although an understandable one--given what the liberal arts have sometimes done to themselves. With judicious reformation, however, the liberal arts *can* be truly liberating (even profitable) in our technological society.

1.

To understand this situation, it is helpful to review some aspects of the history of the liberal arts. The distinction between liberal versus the servile arts--like many aspects of our culture--can be traced to the Greeks. For the Greeks a free man--that is, a person whose actions are governed neither by the immediate needs for food and shelter nor by other human beings--needs a special education for his special way of life.

Most people throughout history--and even today in many parts of the world--have lived a day-to-day existence. But once a day-to-day existence is transcended, then a new way of life comes into being, at least among the ruling class. For Plato and Aristotle (in the 4th century BCE) the cultivation of this new way of life required what was called *paideia*, education for general human excellence rather than limited technical capabilities.

Paideia was not, however, an education for idle uselessness, sophisticated leisure, or abstract intellectual scholarship and debate. It included physical exercise, military training, public speaking and logic, mathematics, astronomy, and music (see Plato, *Republic* II and VII; and Aristotle, *Politics* VII, 13 through VIII, 7). Lest we jump to false conclusions regarding the "useless" character of these last three topics, we should recall that geometry was necessary for surveying and owning property, arithmetic for conducting business, astronomy for navigation, and that music was integral to public festivals and celebration. *Paideia* was thus an eminently useful and practical education for a person who did not work as a slave but had to help guide and govern his society.

The Roman equivalent of *paideia* was called first *humanities*--that which makes one truly human, hence our "humanities"--and then later *artes liberales*--the arts or disciplines of freedom, hence our "liberal arts." But because the idea of freedom is subject to variant interpretations, there have been tensions or conflicts between the political and religious control of the liberal arts curriculum since at least the Roman period.

For instance, on the one hand, Varro, the great Roman polymath of the 1st century BCE, classified learning into nine liberal arts. Two of these were medicine and architecture--both of which certainly enhance humanization and freedom in this-worldly terms. In the early Middle Ages, on the other hand, a liberal education was associated with the great monastic schools, and in this context became integrated into religious or other-worldly concerns. Yet within the religious context, the liberal arts remained eminently practical; *lectio divina* made a real contribution to transcendence.

The traditional liberal arts are, however, seven in number. The first three, the trivium (hence our word "trivial"), were grammar, rhetoric, and logic. These are trivial in the precise sense that they are the necessary prerequisites for any man of affairs. A person in public life must know how to communicate effectively; otherwise he or she will accomplish nothing. The best ideas in the world, if they cannot be explained to others, are not going to play a significant role in public affairs.

The last four of the liberal arts, the quadrivium, are arithmetic, geometry, astronomy, and music. Notice that contrary to common misconceptions, the liberal arts, the humanities, include a substantial proportion of "quantitative thinking." "Math phobia" was not accepted as an excuse for not knowing how to manipulate numbers and engage the world in quantitative terms. Without a basic facility in mathematics, a person--even if he or she could effectively communicate--was severely limited in what he or she could effectively communicate about.

The skills of effective communication and the basics of mathematics were, then, the heart of the traditional liberal arts. Without a solid foundation in these two areas, one just could not exercise one's freedom in a society no longer dominated by the immediate struggle for existence. Without skills in English and mathematics, we could say today, one is limited in a world of high technology to blue collor work--if not unemployment.

But in the course of time various factors have often tended to undermine the vitality of the liberal arts educational program, particularly at the level of university of higher education. This is a complex issue which it is not possible to survey with any depth here. Suffice it to say that among the factors at work have been, first, a democratization of the liberal arts and, second, the defense of special interests by an educational elite.

In the first instance, the core disciplines of the liberal arts have filtered down from the university level and become the basis for all public education. This is, of course, exactly as it should be in a society that aspires to democratic governance. The problem is that such a development has tended to make certain aspects of a university-level education superfluous--provided the primary and secondary schools really do their job.

In the second instance, then, in response to the partially superfluous character of some aspects of a university education, university professoors have tended to make their disciplines even more superfluous--by turning the liberal arts themselves into abstract specializations. In China this engendered the mandarin system of lagely irrelevant examinations administered by an elite class to perpetuate its own status. Over the ocurse of time the liberal arts in the West have often tended to become equally academic, in the bad sense of that word. They have tended to become irrelevant to the man or woman of practical affairs--the very persons the liberal arts were originally intended to serve.

The history of the liberal arts is not, however, all self-interest and deterioration. Throughout the centuries there have been periodic attempts to revive the liberal arts--by rejecting barren scholasticism or useless internal scholarly discussions--to bring the liberal arts back into the real world and to make them what they were originally meant to be.

One interesting and prescient reformation was attempted during the high Middle Ages in Paris by a man named Hugh of St. Victor (12th century). Hugh wanted to complement the traditional seven liberal arts curriculum by what he called the seven mechanical (from the Greek mekhos, means) arts. These seven mechanical arts consisted of weaving, weapons, forging, navigation, agriculture, hunting, medicine, and (interestingly enough) acting.

That Hugh wanted to introduce navigation shows how abstract astronomy had become. That he wanted to introduce agriculture, weaving, forging, hunting, and medicine shows how complex these activities had become. No longer was agriculture a primitive skill dependent on tradition. With the introduction of the mold board plow, horse collar, and crop rotation (see Lynn White Jr., Medieval Technology and Social Change [1962]) there was a need for an examination of the principles involved in what was then modern agriculture. No longer was it sufficient to operate wholly by common sense and intuition.

There have been other revisions and extensions, each trying to make the liberal arts program more realistic and bring it back into line with its original functions--often by enlaging its scope. During the Renaissance there was the revision which first transformed the cathedral schools of the late Middle Ages into the university faculties of law, medicine, theology, and natural philosophy or science, and then incorporated into the curriculum a rediscovery of the classics and their this-worldly humanism. This was the origin of the so-called "professional schools" (from whence our term "professor," meaning originally one who taught the professions). In the 19th century there was a movement to include economics and the social sciences as integral parts of a liberal education. And post World War II American education has witnessed more than one expansion and reformation of higher education--from the creation of the community college system to the elimination of core requirements (in the 1970s) and their reinstitution (in the 1980s), each aimed to make the liberal arts more fully liberating.

2.

It is against this background that current discussions of a "new liberal arts" incorporating "technology literacy" need to be viewed.

As is well documented, liberal arts graduates ultimately out-perform their engineering counterparts in many managerial, administrative, business, and public service occupations. But in the past it has only been after a significant period of on-the-job education in the real world of high technology that liberal arts graduates began to put their "trivial" skills of communication to effective use. Recognition of the need to cut down this lead-time, to make the liberal arts more encompassing, gave birth to the Alfred P. Sloan Foundation's now well-publicized "new liberal arts" grants of over ten million dollars (from 1982 to the present) to stimulate the incorporation of technology into a variety of traditional liberal arts courses.

It is important to recognize, however, that the Sloan Foundation was not the only one to acknowledge the need, nor did it proceed alone. Stretching back to the mid-1970s, there had been developing within the liberal arts field what is now called the STS (science-technology-society) studies movement, spearheaded by social scientists and humanists who perceived the predominant role science and technology had come to play in modern society, and by engineers who argued the need for technology to become aware of its place in the larger social matrix.

Associated with the STS movement was development of philosophy and technology studies research in a wide variety of areas: environmental ethics, technology assessment, energy policy, ethical and political analyses of weapons development and automation, the ontological critique of artificial intelligence, epistemological examination of the engineering sciences and risk assessment methodologies, etc. Indeed, precisely because of the immediately relevant character of STS courses, a substantial number of them necessarily tend to embody the discussion of properly philosophical issues. Nowhere was this more dramatically illustrated than in what has come to be known as bioethics.

It was, then, these two interrelated, pioneering efforts--STS studies and the philosophy of technology--which formed the initial bridge between science-technology and the traditional liberal arts. These are the primary structural elements spanning the "two cultures" hiatus.

In 1980, two years prior to the first Sloan grants, a couple of leaders at Polytechnic University (George Bugliarello, its president, and Donald Hockney, head of the Department of Humanities and Communications) began to develop ideas for a "contemporary liberal arts"--not just as a transformation of various elective courses, but as a whole new core curriculum. The suppot given to these ideas by the Andrew W. Mellon Foundation the next year led directly to the development of one of the most creative American ventures in bringing together technology and the liberal arts--and indirectly to the creation of the first institutional base for pursuit of a broad philosophical understanding of technology. (The foresight of the Mellon Foundation in anticipating other funding agency interests in this area can no doubt be traced in part to its prior support of earlier STS programs as well; Mellon has truly been one of the less acknowledged leaders in reviving the liberal arts.)

Hockney, the director of this program, articulated the philosophy of the Polytechnic liberal arts core curriculum at a conference of the American Society for Engineering Education:

> *It is clear that technology, in large measure, determines the context of human relationships, constitutes a common experience and defines common concerns. It is reasonable to conclude that the study of technological phenomena should be included in the general education component of the curriculum. This calls for nothing less than a new vision of liberal education* (1983 ASEE Annual Conference Proceedings).

With this vision in mind, Polytechnic has developed a core curriculum for all its humanities and social science majors which begins with a course in "Technology and Society in Historical Perspective," and includes courses in computers, mathematics, physics and chemisry, biology, and psychology. After an introduction to "Ethics and Technology," the junior year devotes four courses to the topics of materials, machines, energy, and information. The senior year entails an interdisciplinary seminar and thesis. Next June will witness the graduation of the first students to have completed this new curriculum. (See box for details.)

The unique achievements of this version of the new liberal arts are two-fold. First, technology literacy is not limited to elective courses; it is part of an extensive required core curriculum. Second, technology literacy is recognized as involved with philosophical issues. Indeed, one of Hockney's initial actions was to augment his faculty with someone specializing in the philosophy of technology, and subsequently to encourage the development of the Philosophy & Technology Studies Center. This Center now serves as a coordinating base for the core curriculum, and through collaborative activities the Center enhances and promotes further curriculum development.

Given the fact that philosophy has traditionally been understood as perhaps the most pure--some would say the most abstract--of the liberal arts, this is a remarkable step, one with manifest implications both for this particular program and for philosophy.

Contemporary philosophy, as others have noted, is undergoing an "applied turn." Having for many years pursued its analytic and linguistic skills in a scholastic vacuum, Anglo-American philosophy is today much more aware of the need to address issues of common concern and practical import. This is fortuitous, because in a society where engineers and technicians play a dominant role, only the development of truly philosophic insight into the nature and meaning of modern technology can facilitate the kind of freedom necessary to govern our new creations. The liberal arts in a high technology society thus necessarily contain an inherently philosophical component--one that it is appropriate to recognize and promote.

Model Program in the Polytechnic Liberal Arts Core Curriculum

Freshman

HU 101 and HU 200	Writing and the Humanities I and II
LA 110	Technology and Society in Historical Perspective
LA 120 and LA 121	College Mathematics I and II
LA 125	Introduction to Computers
LA 130	Introduction to the Physical Sciences
SS 104	Contemporary World History

Sophomore

LA 131	Introduction to Biology
LA 132	Introduction to Behavioral Science
LA 140	Ethics and Technology

Junior

LA 141	Materials and Social Issues
LA 142	Machines and Humanity
LA 143	Information, Communication, and Society
LA 144	Energy Technology and Social Issues

Senior

LA 150	Senior Seminar: Making Connectiosn
LA 160	Senior Thesis

N.B. The four junior-level courses are normally team-taught by a member of the arts and sciences faculty and from the engineering faculty.

CARL MITCHAM is Associate Professor of Humanities and Director of the Philosophy and Technology Studies Center, Polytechnic University, 333 Jay St., Brooklyn, NY 11201.

Bull. Sci. Tech. Soc., Vol. 6, pp. 240-245, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

TECHNOLOGY & THE LIBERAL ARTS

John P. Brockway

This paper is concerned with a description of a Program in Technological Studies which is emerging at Davidson College, a traditional liberal arts college. The program, from its inception, has come about in direct response to a challenge made by the Alfred P. Sloan Foundation late in 1981 and 1982. An individual associated with the Alfred P. Sloan Foundation, Stephen White (1981), Director of Special Projects, wrote an article included in an Occasional Paper together with replies, which was published by the Sloan Foundation. In that publication he said,

> *"To believe, in this era, that a man possesses a liberal education who is ignorant of analytical skills and technological skills is to make a mockery of the central concept of liberal education and to ignore the nature of the world in which the graduate will live, and to which he hopes to contribute."*

He argued for a "New Liberal Arts" which included technology and mathematical reasoning. This paper prompted action from the Foundation.

The Sloan Foundation offered challenge grants to the top 33 liberal arts colleges as judged by incoming SAT averages, invited these colleges to participate in a competition for major grants of $250,000. Of these 33 liberal arts schools there were 10 initial winners who were: Carleton, Davidson, Grinnell, Lafayette, Mount Holyoke, Oberlin, Union, Vassar, Wellesley, and Williams. Subsequently, in later competitions 23 additional new liberal arts colleges have received awards ranging from $25,000 to $150,000. They are: Amherst, Bates, Bowdoin, Bryn Mawr, Bucknell, Claremont McKenna, Colby, Colgate, Connecticut, Franklin & Marshall, Hamilton, Haverford, Middlebury, Pomona, Reed, Rust, St. John's, Smith, Spelman, Swarthmore, Trinity, Tuskegee and Wesleyan. The Alfred P. Sloan Foundation also funded universities which were examining curriculum changes, but would also be involved with liberal arts colleges' programs in technology. Those universities participating were: Carnegie-Mellon, Dartmouth, Duke, Georgia Tech, MIT, Princeton, Stanford, Syracuse, the State University of New York at Stony Brook, Washington University in St. Louis, and Yale. To date, more than 58 colleges and universities are participating in what has come to be known as "The Sloan New Liberal Arts Program."

Davidson College's Program in Technological Studies

By the spring of 1986 Davidson College had received from the Alfred P. Sloan Foundation two major grants which would total $250,000 each, which are being matched by grants from IBM, AT&T, and others. Davidson's initial proposal to teach technology at a liberal arts institution had four major components. The committee that was appointed to take charge of the program felt that the program would have permanence in the long run only if the faculty were not only apprised of the technological state and condition of the society, but were prepared in a knowledgeable way to teach it.

The four major components chosen were: Faculty Workshops, Summer Special Projects, Faculty Leaves, and Public Symposia. The workshops were designed for individuals who did not have high technological nor mathematical skills, were targeted toward the humanities, arts, and social science faculty. The first workshops were held in the summers of 1983 and 1984 and were comprised of intensive four-week programs dealing with applied mathematics. Ten Davidson College professors and six J.C. Smith University professors participated in the first workshop. These individuals came from the disciplines of Classics, French, German, History, Music, Psychology, Sociology, and Business. They learned mathematical models, matrix algebra, discrete probability theory, and graphing theory. They were taught by members of the Davidson College Math Department as well as university professors in math from Indiana, University of Pittsburgh, New York University, and Rutgers. The second Applied Mathematics Workshop occurred in the summer of 1984 and involved nine Davidson College professors and four J.C. Smith University professors. Their disciplines were: Classics, Chemistry, Economics, History, Philosophy, Political Science, Psychology, Religion, and Spanish. These individuals concentrated on acquiring knowledge of computer modeling and simulation. They improved their programming skills. They worked in small groups on projects in literature, political science and psychology.

During that same period of time, 1983-1984, Summer Special Projects occurred. This represented the second component. These were largely independent study and research projects conducted by an individual or groups of individuals. They included faculty from economics who concentrated on mathematical descriptions of an econometrics course. Additionally, three individuals who concentrated on making available SPSS packages for preparations in a new computer course for Humanities and Social Science students were involved. Others focused on computer-aided-instructional logic courses in philosophy. Two political scientists and one psychologist studied causal modeling and factor analysis and they improved the research design and analysis courses in both of their disciplines by bringing on stream the SPSS packages. Two psychologists were involved in microcomputers within the experimental psychological laboratory series and one psychologist prepared to teach a course in bioengineering and health technologies. A classics professor studied a mathematical analysis of the aesthetics in classical Greek art and prepared to teach a new course on science and technology in the ancient world. Three professors of French devoted the summer toward computer-aided instructional packages in French. Two mathematicians studied new computer courses for students in humanities and the social sciences, and one mathematics professor engaged in intensive study of the architecture of programming languages. Two sociologists developed course modules on sociological perspectives on technology and they introduced computerized data analysis into an introductory course insociology. One sociologist studied a computer model of the case pressure and flow through the criminal justice system in the local country.

The third component involved supporting faculty leaves. These leaves occurred from 1983 to 1985 and involved six individuals. Professor John Brockway, Department of Psychology, studied bioengineering and health technologies with professors at MIT during the two summers. Professor Larry Ligo, Art Department, studied technology and photographic art at Princeton. Professor Earl MacCormac, Department of Philosophy, studied ethics and values in technology--the case for electric rates at both MIT and the State University of New York at Stony Brook. Professor Mary Thornberry, Political Science, studied public policy and communications technology at the State University of New York at Stony Brook and at Duke University. Professor Benjamin Klein, Depatment of Mathematics, studied discrete mathematics programs at the State University of New York at Stony Brook and at Rutgers University. Professor Robert Maydole, Department of Philosophy, studied technology in freedom at Carnegie-Mellon University.

Each of these individuals, by committing himself or herself to a leave, agreed to produce a public symposium which examined the central issues of technology and the liberal arts which were studied. Six such public symposia have now been held. They have been widely attended, have been supported generally, and have been published. These proceedings are now available. Their titles are: "Technology and Science: Important Distinctions for Liberal Arts Colleges"; "Technology and Values: Decision Theory and Electric Rates"; "Bioengineering and Health Technologies: The Physics, Clinical Applications, Economics and Bioethics of Magnetic Resonance Imaging"; "Photography: A Technological Art Form"; "Telephones and Technology: The Breakup of AT&T"; "Technology and Freedom."

The Place of Technology in Liberal Arts

These public symposia over the last two years brought into sharp focus discussions about the relevant place or role the study of technology occupies in a liberal arts institution. The first symposium, taken as a whole, presented historical arguments which were vitally important in discussions concerning the nature of technology as applied science. The symposium presented historical evidence which strongly refuted this notion, presented case after case of technology which existed prior to the scientific understanding or any competent scientific understanding of the phenomenon in question. When persons would argue that technology was merely applied science, that science discovers, and technology follows, restating that technology merely was applying that which science has discovered, they could now be shown to be incorrect. That view now represents only one small part of the overall technological knowledge picture.

The second symposium focused on technology and values, particularly as they were applied to electric rate decision-making. The symposium asked questions in a public sense about the role of decision-makers, and their sensitivity to ethical issues concerning "life-line" rates, and basic questions of "rights" when applied to electricity. The quagmire of differential rate setting was heatedly debated in the case for rates made in and around San Francisco, where there are now in place more than one hundred different rates paid for electricity.

The third symposium dealt with medical technologies which are usually thought of as benign, adding to the quality of life, promoting the general welfare and contributing to the health of the society. In an environment of a liberal arts educational institute that has produced lots of medical doctors, the symposium highlighted many of the reverse assumptions. Limited resources are being spent on a very few persons due to political pressures or congressional mandate, and technological advancement may be the biggest cost-pusher in the dramatic explosion of medical expenses. No mention was made at this time of the dramatic costs associated with the liability insurance wound inflicted on health care delivery systems today.

Each of these public symposia added to our public discussion of technology's role within the liberal arts, contributed to the conclusion that liberally-educated persons who will assume positions of responsibility in society must know a great deal of technology to be able to debate it. They must be able to speak eloquently, knowledgeably, and articulately or be branded a technopeasant. The symposia brought refinement to the goals of the program.

Refined Goals and Objectives

Essentially speaking, there were three relatively refined objectives by 1985. They were: to present relevant topics in technology and engineering principles to undergraduates as part of their general liberal arts education; to recognize that quantitative reasoning and technology deserve a central place in today's undergraduate curriculum; to recognize that a liberal education must include frequent experience with technology and with quantitative methods of solving problems over a wide range of subjects and fields.

Permanent Change in the Curriculum Depends on Course Development

Course development was encouraged. The program was conceived to have two levels of courses: an Introduction to Technology, and Special Topics courses (upper level). The courses which have come to fruition first have been special topics courses, principally as a result of funded release time. These have included topics of: Bioengineering and Health Technologies (Professor Brockway--Psychology); Sex, Technology and Morality (Professors Case and Stell-Biology and Philosophy); Computers and Society (Professor Epes--German); Technology and Ancient Greek World (Professor French--Classics); Philosophy of Technology (Professor MacCormac--Philosophy). No mention here has been made of the infusion model, where technology is taught as an integral part of an existing course.

There is as yet no consensus about the contents or form of the Introductory Course. In the winter of 1986-87, a faculty seminar, modeled after that suggested and used by Lafayette College, will be tried. Nine faculty will meet once a week for about 15 weeks and then for two weeks after the end of the school year. Our expectations for this seminar differ from that of the Lafayette model in that we expect the outcome of the seminar to have two products: the course syllabus and some faculty members who are willing to risk teaching such a course. A second group of faculty will be recruited to attempt a second approximation during the winter of 1987-88. This would result in a second version of the Introductory Course and possibly, three different faculty members teaching it. Evaluation at that time will be critical.

Other new courses will come on stream fall of 1986-87 including a course entitled "From Petroleum to Penicillin," in chemical engineering taught by Professor J.N. Burnett.

During the next two years at Davidson College, nine faculty members per year will be involved in a faculty seminar. The purpose of the seminar is to meet once a week, to discuss and decide the contents of the inroductory course in technological studies. The objectives of the faculty seminar are two-fold: identify the relevant topics that would be included in an introductory course in technological studies; and identify the faculty members who could team teach such a course. As has been the case at Wellesley, these courses tend to be expensive because they are team taught. Additional funding is being sought.

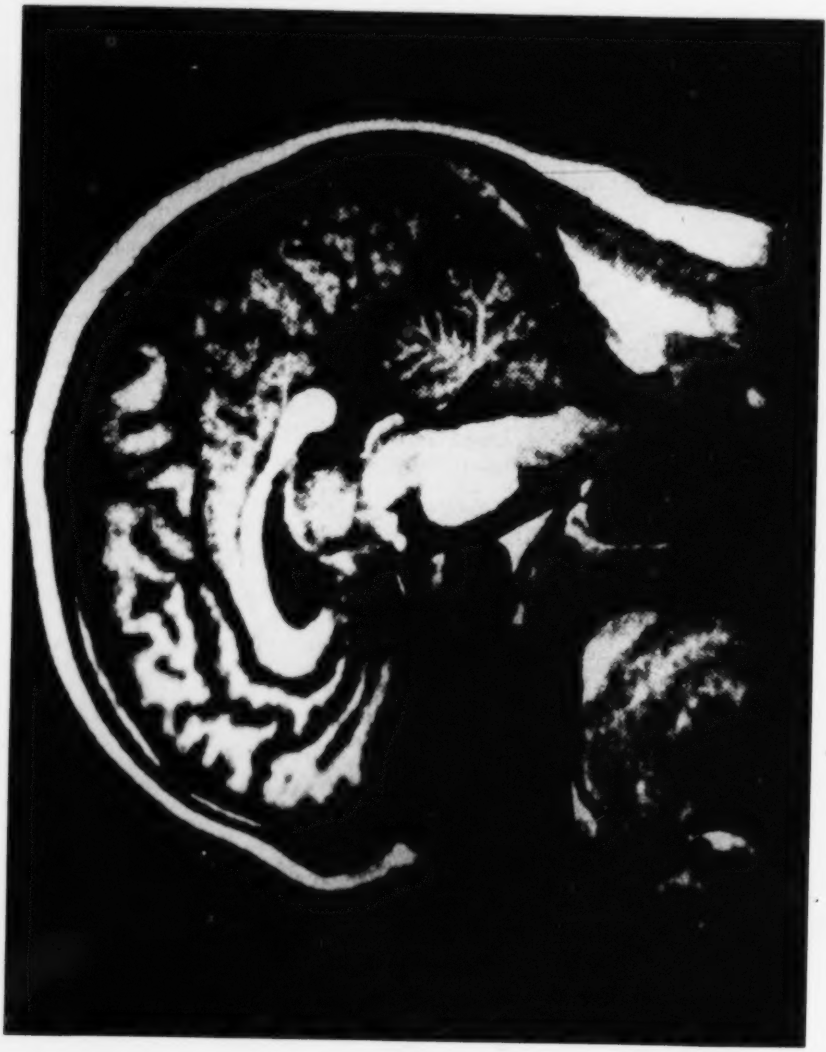
What is envisioned at the end of three years is an introductory series followed by a variety of upper-level, more sophisticated in-depth courses.

Lessons From Special Courses

The character of the special courses in the Technology Studies Program is that as they are interdisciplinary they require a quasi-team taught approach. The course in Bioengineering and Health Technologies will serve as an example.

This course examines five major medical technologies in a highly particular manner: students are expected to learn the physics, clinical application, economics, politics, psychology and ethics of each of the technologies, in that order. The technologies include: Magnetic Resonance Imaging (MRI), Cardiac Electrophysiology-Pacemakers and Angioplasties, End Stage Renal Disease, Lasers, and Cochlear Protheses.

In each of these areas, the class hears from experts, either members of the faculty, or physicians at a nearby teaching hospital (Charlotte Memorial). The class visits regularly the laboratories where the technology is being used. Usually it is linked inextricably to an individual's life, or quality of life. These clinical experiences (trips to the hospital, laboratories) radically alter the motivational level of the students, and on student evaluation forms, are rated as one of the most desirable aspects of the course.



Sagital section human head Magnetic Resonance Imaging

The actual effect of seeing the machine's being connected to a human being has not been measured directly. However, in all classes taught to date, this aspect seemed to be critical to the student's insight into the ethical problems, their motivation to learn the more difficult computational aspects of the physics, and their understanding of the evaluation of cost-benefit analyses as sole criterion for machine success.

It is not overstatement to say the actual experience of seeing the machines connected to and being used by individuals for their health and well-being provides episodic knowledge, rather than just semantic approximations to it. This is a radically different form of knowledge, which affects what people know over time in a different fashion. It may be that it is just this kind of knowledge which has somehow separated out the liberal arts student from the technologically oriented student, at some point prior to making the which-college decision.

When students see the images derived from Magnetic Resonance Imaging, they not only see the image produced, but they see the person who is lying stock still in the scanner, they know how important the machine is to that person's life, whether it is for diagnosis, as in the case of MRI or in the case of treatment, as with artificial kidneys. They see the physicians who have to base their decisions and actions on the quality, clarity, and sophistication of the technology being studied. They ask, "Did you learn about this technology in medical school?," and the answer is always "No!" They know these things affectively as well as academically.

These special courses narrow thought, yet widen it. They force the student to become articulate not merely about technology, but in technology. They force the student to integrate radically differing knowledge sets such as physics and ethics, politics and application design. They enable the student to think about the role that technology "ought to" play in society, as well as the role it seems to be playing.

Reference

White, S. The New Liberal Arts: An Exchange of Views (Alfred P. Sloan Foundation, 1981, p. 7).

JOHN P. BROCKWAY is Associate Professor in the Department of Psychology and Co-Director of the Sloan Program in Technological Studies at Davidson College, Davidson, NC 28036.

Bull. Sci. Tech. Soc., Vol. 6, pp. 246-254, 1986. Printed in the USA.
0270-4676/86 STS Press.

RESEARCH IN STS STUDIES

Judith Adams, Paul Durbin and Rachelle Hollander

> The challenge is there: the social problems of technology--problems related to the environment, the energy crisis, traffic problems, social engineering--so discipline-spanning in their interactions with other realms of life . . . are, at bottom, problems of social and political values . . . . They cannot be solved, in any realistic and adequate way, without the collaboration of philosopher-generalists, broad humanists, and social science generalists working with engineers and technological experts . . . . The more multidisciplinary technological problems become, the more important such programs [in science, technology, and society] will turn out to be. Hans Lenk, Research in Philosophy & Technology 7 (1984): 50, 52.

During approximately the past two decades Science, Technology and Society has steadily developed as an interdisciplinary field of study. Emerging from a handful of innovative courses in the late 1960s, the field has today become recognized as serving a vital role in society's ongoing attempt to understand the complex social context within which science and technology are inextricably entwined. However, it is our contention that if STS studies is to achieve a truly secure position alongside the traditional academic disciplines, it needs to establish research credentials in addition to its already well-deserved reputation for creative curriculum design. While numerous achievements have already been realized in terms of STS research, both needs and opportunities still remain. This three-part essay offers a selected overview of those achievements, raises central questions regarding the essence of STS as an academic discipline, and suggests a number of organizational strategies and funding opportunities currently available to STS researchers.

I. Overview

Metaphorically one might envision the field of STS studies as somewhat akin to a peanut butter sandwich without the bread. Such a vision would emphasize the growing awareness of the complexity, the sticky and cohesive nature, if you will, of the relationship of technology and society. Those whose are exploring this relationship initially find themselves in a seemingly formless mass of information where it takes great skill, knowledge, and perseverance to isolate interconnected factors and elucidate cause and effect directional flows. In an encompassing view, STS studies can be seen to concern themselves with issues of what or who is in control, and the causal relationships surrounding technical innovation and social change. Publication in the STS field has consistently demonstrated a growing concern to document the complexity of the relationship between development of specific technologies and social factors.

Many of the now classic studies in the field, those which served to shape and give direction to research, attempted to analyze the emerging autonomous nature of technology. Some detactors now rather simplistically label these authors "Luddites" because they adhere to a theory of technological determinism. Actually most of these works are designed as warnings against specific observed tendencies considered to be detrimental to society as a whole.

Jacques Ellul, in his early work, The Technological Society (Knopf, 1964), demonstrates the growing pervasiveness of "technique" as the organizing principle of all human activities. The machine is seen as the ideal form toward which technique strives, but technique is evident everywhere--in management styles, advertising, political systems. In his later work, The Technological System (Continuum, 1980), Ellul makes his case for the belief that Technology now serves as the "autonomous mediator" of the totality of elements in our world. When, for instance, the computer enters administrative practice, Ellul contends that we refashion administration to imitate the computer.

In Autonomous Technology: Technics-Out-Of-Control As a Theme in Political Thought (M.I.T., 1977), Langdon Winner presents a balanced analysis of the prevalence of the belief that technology "has gotten out of control and follows its own course, independent of human direction." He actually refutes the modern providential conception of history as a "march of progress" with technology as the drum master. Instead, he sees technological change as currents of innovation moving in directionless patterns toward uncertain destinations.

Reactionary, rather immediate personal response to this view of technology as "out of control" is perhaps most clearly demonstrated by the work of Samuel Florman. The Existential Pleasure of Engineering (St. Martin's, 1975) is an eloquent apology for the work of the engineer, and it is, along with his later volume Blaming Technology (St. Martin's, 1982), permeated by the conceptualization of technology as value free. If damage results from specific technologies, then responsibility must be placed with those in control--politicians, industrial management.

Much of the more recent STS literature, reacting and building on the view of technology as autonomous, is producing careful, extensively researched studies which elucidate the complexities of the nature of specific technologies, along with the cultural changes caused by them, and most notably, the role of exterior factors in the shaping, acceptance, or diffusion of the technologies. They are attempting to provide, as John Staudenmaier proposes in his recent work, Technology's Storytellers (M.I.T., 1985), a "contextual integration" of technological design with its cultural "ambience." They are looking not only at the social effects of technologies but also at the often crucial roles of social factors in the shaping of technologies. The autonomous nature of technology, then, is being critically challenged.

Research has tended to cluster around particular technologies that have visibly changed the cultural fabric of the West, such as energy development including electrification and nuclear power, all transportation technologies from the bicycle to space travel, manufacturing systems and machine tools, communications technologies, and computers. These technologies have represented, or indeed have become metaphors for the familiar three-stage phenomena of technological development, that is, the growth of scientific research, the expansion of the technology, and the advent of rapid social change. In some cases, distinctions can be observed in the focus of earlier as compared with more recent scholarship concerned with a specific technology or related technologies. A look at these changes in several focused areas can serve to demonstrate trends in th STS literature.

Aviation

In 1970, Norman Mailer, in Of a Fire on the Moon (Little, Brown, 1970), voices his dismay at the lack of romance evident in the facilities and the personnel surrounding the Apollo moon missions. He finds the colossal Spacecraft Center to be gray and windowless rather than the "first cathedral of the Age of Technology." His reaction is boredom rather than the wonder felt by Henry Adams as he first viewed the Corliss Engine. But Mailer attempts to restore magic in the venture. He contrives, with, unfortunately, too much sentimentality, to see the moon mission as an exploration, via technology, of the passions and insticts which have made man worship the machine. A moon rock becomes a romantic icon. We are not convinced.

By 1979 Tom Wolfe was cleverly and eloquently debunking the aura of the space program. The Right Stuff (Farrar, Straus, Giroux, 1979) for an astronaut turns out to be: machine-like response capability; an ability to squelch any intellectual instincts or curiosity which might interfere with the strict schedule of a programmed flight; and early on, as Alan Shepard discovered, the ability to control one's bladder during long lift-off days.

Moving beyond the debunking mission, Joseph Corn studies the emotional response of Americans to aviation in The Winged Gospel: America's Romance with Aviation, 1900-1950 (Oxford, 1983). He attempts to understand the "messianic expectations" of aviation enthusiasts and the consequences of such attitudes on American culture. As with most new large-scale technologies, the airplane was seen to embody "progress" at first, but Corn concentrates on the evolution of that metaphor as it became reduced through commonness and military utilization to merely a vehicle or a weapon.

Two recent studies of the Supersonic Transport demonstrate a shift in focus away from the social impact of the technology around to the role of social factors in the acceptance and development of a technological innovation. The American scene is chronicled by Mel Horwitch in Clipped Wings: The American SST Conflict (M.I.T., 1982), in which he moves from the engineering research problems to the political debate over government funding of commercial interests, to the effective, organized citizen activism over environmental harm. The European supersonic aircraft effort is documented in a 1985 study by Elliot J. Feldman, titled Concorde and Dissent: Explaining High Technology Project Failures in Britain and France (Cambridge, 1985). The study is a fine example of extensive research into the essential role of political establishments in the shaping of technologies. Feldman is careful to juxtapose the rational planning expertise of the French with what he sees as the amateurishness of the British. The stereotypical idea that technology rules the political scene is corrected to provide an understanding of how political policy making can doom the commercial viability of a new technology.

Electrification

Historical views of the advent of electrification also indicate the shaping effects of social and political factors which are external to the technology itself. Harold Passer's 1972 study, The Electrical Manufacturers, 1865-1900 (Harvard, 1972), focuses on the role of the entrepreneur and the trend toward standardization. D. Clayton Brown's Electricity For Rural America: The Fight for the REA (Greenwood, 1980) reveals the bureaucratic resistance faced by the Rural Electrification Administration in its drive to make electricity available to rural America.

Thomas Parke Hughes' prize-winning 1983 study, Networks of Power: Electrification In Western Society, 1880-1930 (Johns Hopkins, 1983), will probabiy serve as a model for much future research on the diffusion and transfer of specific technologies. Hughes presents a thoroughly researched, extremely effective comparative treatment of the dispersion of electric power in various locales--New York, Chicago, Berlin, London, and in rural areas, including the Lehigh Valley in Pennsylvania. Advancing beyond the scope of earlier scholarship, he concentrates on uncovering the reasons why a new technology enthusiastically and easily accepted in one locale may encounter insurmountable difficulties elsewhere. For example, attempts to transplant Edison's electric power system designed for New York City were largely successful in Berlin but failed in London. Hughes examines, then, the failure of the expected and the inability to explain technological successes and failures by limiting reference to the technology itself. External forces are shown to be in control--political systems, social values, business power structures. It is evident that the technology itself is far from autonomous; the cultural complex "engineers" the technology in the sense that it shapes, diffuses, and familiarizes the innovation.

Computers

The STS literature surrounding computers particularly shows a movement from an interest in broad-based social impact to a concern for the personal, individual experience generated by contact with the technology.

Joseph Weizenbaum's Computer Power and Human Reason (Freeman, 1976) is an early warning of the profound social effects of a world image which, he contends, has been transformed to resemble a computer. Since we have not demonstrated the ability to make computers wise, he considers that the debate concerning artificial intelligence will not be settled by what conceivably "can" be done, but by the ethical issue of whether we "ought" to give computers tasks that demand wisdom.

Sherry Turkle is able to build on the foundation provided for Weizenbaum by narrowing the scope of The Second Self: Computers and the Human Spirit (Simon and Schuster, 1984) to illuminate the reasons and the changes in modes of thinking experienced by individuals as they become familiar with compuers. The strongest segment of her study deals with children. She documents the machine's influence on children's conceptions of themselves. For instance, Turkle demonstrates that a shift has occurred from the Freudian conception of the self as fundamentally sexual, to the technological view of man as machine. She also thoroughly studies children's conceptions of the computer itself, whether it is alive, whether it knows good from bad. For example, for young children, movement is often the criteria by which they decide whether something is alive. The computer and electronic games which can talk, play, teach, and win have changed this view. Suddenly the relevant criteria of aliveness are not physical or mechanical but psychological: children ponder "Are their electronic games aware, are they conscious, do they have feelings, do they play fair, or do they cheat?" Seven-year-old Robert, frustrated when Merlin, a tic-tac-toe game, would not let him win the same way twice, complained "Merlin is a cheating machine. And if you cheat, you're alive." Traditionally, western science has drawn a firm line between worlds of physics and psychology. Turkle's findings indicate that the computer may serve to dissolve that barrier.

Emerging Areas

Several areas, some of which may have a certain urgency attached to them, offer opportunities for research at this time--first, artificial intelligence. Thomas Pynchon, in an October 28, 1984, article in the New York Times, entitled "Is It OK To Be A Luddite?," contends that "the next great challenge to watch out for will come . . . when the curves of research and development in artificial intelligence, molecular biology and robotics all converge." There has been significant press lately about advances in artificial intelligence, particularly the plan to program entire encyclopedias within computer memories to provide a base of knowledge for automated reasoning processes. The artificial intelligence community is attracted at present to developing medical uses for their advances. This tactic is seen by some to be generated by a belief that medical technologies are quickly accepted by the public and funding is relatively forthcoming. A timely exploration of the implications of these advances would be welcome.

The role of women in technology has received a significant amount of attention in recent years, notably Joan Rothschild's edited collection, Machine Ex Dea: Feminist Perspectives on Technology (Pergamon, 1983), as well as Ruth Swartz Cowan's examination of household technologies, More Work for Mother (Basic, 1983). This literature concerns itself with the conception of women as users of technology and men as inventors. Many of the contributors examine how various technologies have been formulated to reinforce male supremacy. The effects of male domination of technology need extensive, systematic investigation. In addition, Ruth Hubbard, in her foreward to Machina Ex Dea, remainds us that "different social formations have integrated technology differently." Comparative studies regarding women and specific emerging technologies in differing locales could prove to be enlightening, as would studies not related just to women but providing cross-national comparisons of the acceptance and reaction to the transfer of certain technologies.

Thorough research on the corporate process of acceptance of risky technological innovations is also scanty. A good example would be the Dalkon Shield case. What factors in the corporate setting insured the promotion and production of this product despite early warnings? It is already evident from emerging information that economic gain was only one element--corporate power structures and egos played significant roles.

Perhaps most needed at present are careful studies which demonstrate that technical and scientific facts are not enough to solve social controversies. Even interdisciplinary scholars still rely too narrowly on science to support their views, or they regretfully believe that scientific evidence is the only route to acceptance and an audience for their views. Immediately coming to mind is the present attempt to defuse the controversy surrounding embryo research and even abortion by achieving a scientific determination of the moment of individualization, that is, when the fertilized ovum or zygote reaches the state where it can no longer split to become twins and can thus be said to have achieved the status of an individual. It is felt that if this stage can be accurately determined, then use as research subjects of embryos which have not yet reached this point of growth may be publicly accepted.

Recent STS literature, then, points to stronger emphasis on the role of social factors in the shaping of various technologies. It also demonstrates a curiosity about the distinctive responses of individuals to technologies, and a concern for the importance of the emergence of metaphor surrounding technological advances. The field now demands studies which provide a thorough cultural integration of technological innovations.

II. Essence

In order for STS to gain academic legitimacy and respectability, the field must develop from this initial research base while retaining a broad, interdisciplinary--even anti-academic--focus. What are the realistic hopes for this taking place? The answer lies in the responses to a series of more specific, interrelated questiosn.

1. Is STS an academic field or discipline in any acceptable sense? To answer this question, it is helpful to look at an established field that has some overlap with STS--the history of technology--and a brief review of John Staudenmaier's Technology's Storytellers (MIT, 1985) is particularly instructive. What Staudenmaier would tell STS scholars is that a field cannot emerge until there is more than just a constituency of scholars. There must be a focus of genuine intellectual dialogue to constitute disciplinary interaction; authors must recognize common thematic questions and build up a body of literature by reacting to one another's work. Staudenmaier is convinced that the history of technology did not begin to develop such a focus until historians of technology hit upon the theme of contextual research--seeing technological developments against a background of social context--which differentiated them from primarily internalist historians of science at the time.

2. What are some of the criteria for deciding when a new field has emerged? The lesson of The Organization of Knowledge in Modern America, 1860-1920 (Johns Hopkins, 1979), ed. Alexandra Oleson and John Voss, would seem to be summed up best--for the major academic fields in the U.S. in that crucial sixty-year period--by historian John Higham in his lead-off essay. Though Higham's subject is specialization, his real concern is to outline (in a preliminary way preparing for the other articles in the volume) how an ideal of research, of scholarship that builds progressively on the work of others, came to be institutionalized in a peculiar way in the United States: in the Ph.D. as the ideal certifying mark of the academic specialist or researcher; in departments as

societies of specialized equals; in agencies to sponsor research; and in the importance accorded to authoritative reference works as the measure of progress. Charles Rosenberg ends the volume, commenting indirectly on the intervening contributions, by suggesting crucial themes for the understanding of academic specialization: the knowledge-society relationship is structured by institutional contexts; knowledge is a key factor in this, affecting as well as being affected by institutional arrangements; and changes in knowledge societies parallel changes in society at large--legitimation of academic specialities and professional societies, social recognition of vocations or callings, the degree of prestige and financial reward, etc., are aspects of the relationships between these groups and the larger society.

To oversimplify: whether a field of research can legitimately claim to be such is as much a function of institutionalized research and social recognition as anything else.

3. Is there a lesson to be drawn for the STS field? The lesson would appear obvious. For there to be a viable field, there must be something closely resembling an academic department as an institutional base, with graduate programs to train future researchers, and publishing outlets for their work and that of their professors. Furthermore, such outlets must have focusing thematic questions that generate a true dialogue in the sense suggested by Staudenmaier. In other words, a genuine field of scholarship cannot, in the common cliche, be continually starting over again--and again and again. There must be progress, research built upon others' research.

4. Are there publishing outlets for STS research? As a grab-bag answer, one can cite Science, Technology and Human Values, Technology and Society, Technology in Society, Social Studies of Science, etc.; and certain specialized journals or series that are open to STS contributions: Technology and Culture, Research in Philosophy and Technology, Environmental Ethics, and similar publishing outlets. But the quite legitimate question is whether any of these yet constitutes a disciplinary (or--and more about that in a moment--interdisciplinary) focus for the intellectual dialogue that constitutes true research in the socially accepted sense. Are there thematic questions? Does research build upon research in a cumulative fashion?

5. Are there graduate training programs in STS? There are programs that claim to be interdiscplinary, such as MIT's Science, Technology, and Society, or Pennsylvania's Department of the History and Sociology of Science, or Indiana's History and Philosophy of Science. There are technology policy graduate programs (typically only at the master's level), e.g., at MIT, Georgia Tech, and Washington University. There is at least one budding research institute: the Philosophy and Technology Studies Center at the Polytechnic Institute of New York. And there is the new Science and Technology studies Ph.D. program being inaugurated at Virginia Polytechnic Institute--with the possibility of one to follow shortly at Rensselaer Polytechnic Institute and another possibility of doing Ph.D. research of that sort in the Center for Applied Philosophy and Ethics in the Professions at the University of Florida.

Again the question arises: Will all this ferment generate a tradition of research and scholarship that will be socially recognized by the usual academic standards?

6. Is the academic model the appropriate one for an interdisciplinary STS field? It could be objected that everything said so far about opportunities for research in the STS field is inappropriate. The field as it is emerging is multi- or interdisciplinary, and it should not be forced into a mold that may have been appropriate to the rise of the modern American university but that is strongly resisted by many STS scholars.

Without a doubt, every one of the fields surveyed in The Organization of Knowledge in Modern America has become a narrow speciality--or has spun off a half dozen other still narrower subspecialties. Only a small number of respected areas of academic concentration have remained genuinely interdisciplinary: American Studies, Popular Culture, and some "area" studies (Renaissance, Eighteenth Century). Can the STS field foster research and still retain its desired multi- or interdisciplinary character?

Hopefully, there can develop a genuinely cumulative intellectual dialogue that will not turn academic: "for specialists only." The odds against this are great, but the need for breadth in STS studies is equally great.

III. Strategies

Even in the absence of a truly interdisciplinary STS field in the sense outlined above, there are approaches available to the STS community for fostering such interaction and research. One way to look at the field of STS is as a series of umbrellas with many segments that all touch at a point. The umbrellas can also intersect with each other in all manners and times. We can allow the different segments to represent different disciplines in contact with each other on issues, which themselves could be classified in various ways or at various levels. In constructing our umbrellas what we have to ask ourselves is how do we select the most useful segments and issues along two parameters: academic or intellectual growth and social well-being.

Coalition building is one approach to dealing with the question. Two kinds of coalitions are needed. One kind involves coalitions among those academic disciplines and traditions that are equipped to tackle these issues in scientifically and intellectually respectable ways. The other involves coalitions between professional, academic, and other societies and organizations in order to encourage and to support the development of the field, including the development of the first kind of coalitions, and to monitor its progress.

Without being able to identify all individual groups by name, there are two kinds of academically oriented associations that must be involved. One is a subset of professional organizations, the other a subset of educational organizations. Another kind of organization that must be involved is governmental. It will also be worthwhile to involve some foundations or consortia of foundations or universities, trade or industry association groups, labor groups, environmental organizations, but certainly at this stage efforts can begin by drawing out and developing support in professional and educational groups and in government.

Before identifying specific professional groups and governmental agencies, it is important to identify the intellectual tasks that should be part of their efforts on behalf of STS. Basically, they need to help STS identify, from the perspectives of their memberships or constituencies, the potential contributions of the field. Secondly, they need to let the STS community know what their members or staff or consultants or researchers are doing in this field, and with whom, and what can be done or needs to be done next. Also, they need to interact with the other kinds of organizations whose recognition is required for there to be a real field.

Two professional societies on which it would be profitable right now to concentrate are the American Association for the Advancement of Science and the Society for the Social Studies of Science.

STS can accomplish a great deal through the AAAS structure. AAAS has nearly 300 affiliated societies and academies. Several AAAS committees deal with STS issues, and AAAS sponsors the Professional Society Ethics Group. In addition, there are the sections organized along disciplinary lines. Perhaps the recent name change of Section X, from General to Societal Impacts of Science and Engineering, shows the increasing entrenchment of STS in the Association. These channels need further exploration.

The Society for the Social Studies of Science is a young, interdisciplinary, international society, and its members are often active members of other societies. It publishes a recently expanded journal, Science and Technology Studies, under the editorial direction of Susan Cozzens at the National Science Foundation and Daryl Chubin at the Technology and Science Policy Program at Georgia Institute of Technology. A section of the journal reports on articles and special items or events published on STS issues in other newsletters, such as Lehigh University's STS Curriculum Newsletter, the Bulletin of Science, Technology, and Society, and EASST, the newsletter of the European Association for the Study of Science and Technology, or in proceedings and journals of other professional associations. This effort may serve informally as a coalition-building device; and it might be time to develop some formalized linkages as well. (Another viable candidate for the position of informal coordinator is the journal Science, Technology, and Human Values.)

There are several other social science and humanities associations that, of course, need to be involved: the Consortium of Social Science Associations, the Society for the History of Technology (a COSSA affiliate), the History of Science Society, the Philosophy of Science Association, and the American Philosophical Association.

A very new and hopeful development for STS watchers is the initiative to establish a network among ethics centers being undertaken by John Wilcox of the Center for Professional Ethics at Manhattan College in Riverdale, NY. Currently, Mark Frankel of the Cnter for the Study of Ethics in the Professions at the Illinois Institute of Technology is compiling a list of centers, and proposals for meetings and communications hookups are being developed.

Interestingly, in considering the appropriate academic organizations to involve, none of the big college or university affiliated groups leaps to mind. This may indicate a place where some initial educational and lobbying efforts need to be made to establish a beachhead and create legitimacy.

There are two established educationally oriented groups that can and would help enhance STS. They are the Association of Science-Technology Centers and the National Science Teachers Association. The former is a consortium whose members are science and technology centers. They are interested in issues and exhibits that will draw audiences of children and adults to their buildings. The National Science Teachers Association is also well known to this readership. It is also likely to be an important communications link with such programs as the Science through Science, Technology and Society Project at The Pennsylvania State University.

Private foundations interested in STS issues have always been sources of sporadic support for education programs, while the governmental agencies most accessible to persons looking for support for STS studies probably remain the National Science Foundation and the National Endowment for the Humanities. Also there is the Extramural Program at the National Library of Medicine for scholars in the history of medicine. Other agencies lack interest in mounting sustained programs of research support, although specific interests arise from time to time.

For example, there may be some interest in innovative educational programs though the Fund for the Improvement of Post-Secondary Education at the Department of Education. The Department of Defense sponsors special projects periodically, and there is the Journal of Military Ethics published by the Air Force Academy. The Department of Energy supported an innovative project in energy education by the League of Women Voters back in the days of the energy crisis; now that Department seems to have money for community education work in states with radioactive waste siting problems, although contractors do much of this work. The Administrator of the Environmental Protection Agency recently announced a new push on risk communication studies; the EPA regional offices are interested in community education about hazards. Different institutes at the National Institutes of Health have helped the National Science Foundation support studies on ethical and value issues in the development of the artificial heart, new gene intervention techniques, biological monitoring technologies in the workplace, and risk assessment procedures.

Given these circumstances, STS may wish to focus its efforts on the National Science Foundation and the National Endowment for the Humanities, particularly when it comes to research support. This may be true in the curriculum development area as well. It will come as no surprise that the prospects for substantial new initiatives arising from substantial new investments are bleak, but this is not really new. One can perhaps say that there are more problems now, but one can also say that there are more opportunities, because there are more people working in this field who have organizational bases for support, and who are not going to stop working. STS must interest people in a position to influence important others. And STS does have achievements to exhibit when trying to wield such influence.

The major points of contact right now at NSF and at NEH are the Ethics and Values activity and the Humanities, Science, and Technology program, respectively; but STS researchers cannot afford to limit their contacts in these agencies to these two programs. They have to begin a concerted effort to find out what research or related efforts are being supported in the other programs and divisions of the agencies. For instance, what is the Directorate of Science and Engienering Education at NSF planning next in this area? What are the programs in the Social and Economic Sciences Division supporting? What are the plans at the Endowment? How can STS generate support?

Can we generate inter-agency interactions around STS issues, maybe encouraging NSF or the Endowment to take the lead? Are there useful projects or information STS can offer to the mission-oriented agencies with responsibilities for research and development? Although STSers are peculiarly sensitive to the difficulties of cross-cultural communication, there are real opportunities for cultivating support and interest in the federal agencies and for building interdisciplinary coalitions.

Conclusion

In conclusion, then, there is obviously a long way to go and a number of crucial questions are in need of answers before STS can be said to be firmly established as an academic discipline. However, the evidence of current STS scholarship and the opportunity for further research and coalition building suggests that the establishment of academic legitimacy, while still retaining its interdisciplinary essence, is well within the reach of STS.

JUDITH ADAMS is with the Humanities Division in the Library at Oklahoma State University, Stillwater, OK 74078.

PAUL DURBIN is Professor of Philosophy in the Center for Science and Culture, University of Delaware, Newark, DE 19716.

RACHELE HOLLANDER is Program Director in the Ethics and Values in Science and Technology Program, National Science Foundation, Washington, DC 20550.

Bull. Sci. Tech. Soc., Vol. 6, pp. 255-256, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

STS AT LEHIGH UNIVERSITY

Stephen H. Cutcliffe

"To create educational experiences which bring humanistic perspective to the application and evaluation of technology." With this goal in mind Lehigh University in 1972 launched a major interdisciplinary curriculum development project entitled Humanities Perspectives on Technology and later renamed the Science, Technology, and Society Program. Like many other nascent science, technology, and society activities, the STS Program emerged in part out of the widespread social upheavals of the 1960s and early 1970s. Serious questions had begun to be raised about the beneficence of science and technology and whether they were the unalloyed blessings that society had previously thought them to be. As the STS field began to coalesce and as the Lehigh program matured it became commonplace to view science and technology from the perspective of a social process interpretation. On this view science and technology are seen as shaped and influenced by societal values, which, in turn are affected by impacts deriving from scientific knowledge and technological innovations. Thus, the STS Program at Lehigh serves as a common ground from which to explore the relations between ideas, machines, and values.

The STS Program includes over 50 courses, offering approximately 20 each semester. Topics range from the nature of scientific theories to the nature of the nuclear power industry, from the history of the machine in America to medical ethics, from the politics of oil to the economics of environmentalism, and from the influence of technology on art, music and literature to the influence of philosophy and religion on science and technology.

Lehigh's STS courses are divided into four "tracks" within which courses with a common conceptual orientation are clustered:

1. science, technology and society--courses analyzing the economics, the national and international politics and the social policy implications of research and innovation;

2. science, technology and human values--courses dealing with the ethical, philosophical and religious impacts of the products of science and technology;

3. engineering and society--courses specially designed for students not majoring in science or engineering, treating applied science and engineering as elements in the social process determining their practice;

4. science, technology and Western culture--courses dealing with the history and sociology of science and technology.

Students who are particularly interested may take a minor in Science, Technology and Society Studies. The minor consists of eighteen hours of course work including the introductory "Technology and Human Values" and five more courses, four of which must be in a single track. The minor program is open to students from all colleges and provides a way to help focus STS studies. While the absolute number of students electing to minor in STS is not overly large, approximately 85% of all Lehigh undergraduates do take at least one STS course before graduating.

From a variety of perspectives then, Lehigh's STS courses provide a vehicle for entering into a systematic confrontation with some of the major issues of our time involving the exercise of deliberate social and political control over science and technology. For example, are science and technology autonomous forces to which we must adapt and into whose hands the future is given, or are they derivative, expressing prevailing social, economic and even religious commitments for which we are responsible? Are science and engineering objective activities, keyed to facts and logic and immutable laws of nature, or do they embody subjective value judgments reflecting ultimately political decisions?

In conjunction with its STS curricular activities, Lehigh has also established a Technology Studies Resource Center. The TSRC is engaged in the creation and dissemination of materials and programming that will lead to a more useful understanding of technology on the part of a wide range of audiences, especially their understanding of the mutual interaction of technology and social institutions and values. The Center serves as a focus for academics from all disciplines to collaborate in pursuing research and educational opportunities in technology studies, on and off campus, with academic colleagues and in conjunction with non-academic sponsors. TSRC activities fall into several areas: the development and dissemination of resource materials, professional development programming, and educational programming.

The Center publishes the Science, Technology, and Society Curriculum Development Newsletter which includes short articles on the theoretical and speculative aspects of curriculum development, in-depth course descriptions, reviews of texts and audio-visual materials, and an annotated bibliography of current books and articles in the STS field.

The Center also sponsors a Regional Colloquium in Technology Studies, the proceedings of which are published in a Working Papers Series. The Colloquium offers scholars within a reasonable distance of Lehigh the opportunity to gather periodically to hear about and to discuss current research in the field.

The Center also serves as a clearinghouse for information on people, curricula and materials resources in technology studies. This includes the collection and distribution of model course syllabi. The integration of technology studies material into existing secondary school curricula and the development of better courses in science and mathematics in cooperation with regional teachers is also an important function of the Center.

Finally, the STS Program and the TSRC together have recently embarked upon the publication of a new series of works entitled Research in Technology Studies. The goal of the series is to produce theme volumes consisting of essays centered around important topics such as Technology and the Ideology of Progress. The TSRC thus complements the curricular focus of the STS Program by providing a range of professional development and service functions for the national, even international, STS community.

STEPHEN H. CUTCLIFFE is Professor of STS at Lehigh University, Bethlehem, PA 18015 and Editor of the Curriculum Newsletter Science, Technology & Society.

Bull. Sci. Tech. Soc., Vol. 6, pp. 257-258, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

SCIENCE, TECHNOLOGY AND SOCIETY IN COMMUNITY COLLEGES: AN INTRODUCTION

Corrinne Caldwell

Science, Technology and Society (STS) has become an accepted course of study in a large number of four-year colleges and universities. However, community colleges which offer fully half of all undergraduate education do not have a comparable wealth of STS offerings. Several reasons for this dearth of interest emerge. Modern comprehensive community colleges have three principal roles: transfer education, career education, and non-traditional learning for a wide variety of career-related and recreational purposes. None of these roles have required or even made possible the level of curricular creativity and autonomy required for the implementation of STS courses. Transfer curricula usually adhere quite rigidly to the more easily articulated liberal arts and sciences. Career curricula have the burden of an ever-expanding knowledge and skills base to cover and the regulation of external accrediting bodies. General interest offerings must first and foremost meet their enrollment quotas, which is difficult to do with new, relatively unknown offering such as STS.

All of the above reasons sound valid and important. Why then should a community college educator be concerned with education about science and technology, even for non-scientists and technologists? The usual arguments about our world changing as a result of science and technology are even more valid for community college students. Community college students in ever-increasing numbers are graduating in technology-related curricula. They will be the people with the "hands on" responsibility for implementing technology. Frequently their only formal post-secondary education will be at the community college. If the community colleges miss the opportunity to engage them in a meaningful understanding of the societal implications of their future work, there may be no other chance. Society risks the prospect of technology being operated and managed by technicians who have not had the oppotunity to thoroughly understand the larger context of their work. Students graduating from non-technical programs also need exposure to the principles of STS. These students will be joining their more technologically oriented colleagues in a world defined by technology. They are at risk of being unable to understand science and technology related issues fully enough for adequate participation as informed citizens.

Clearly more than one kind of STS offering is needed in community college programs. At present, the small group of offerings is divided into programs focusing on technological literacy for the non-scientist/technician and offerings focusing on the philosophy and values inherent in technology for the technician. There is also a small group of courses focusing on more creative and possibly alternative ways to deal with technology and its societal demands. I see these approaches as complimentary, not conflicting. There is space in both kinds of curricula for their inclusion. Most community college programs require some mathematics or physical science for non-technology and non-science majors. Many would argue that the only way to learn science is by being exposed to an introductory course in a particular discipline. I would argue that this approach feels irrelevant and often actually becomes so to the non-science student. Whereas, an equally demanding offering, exploring the impact of that science to their daily lives, can be both relevant and rigorous. The technology student is required to take at least 12 hours of general education, including the humanities and social sciences. Within these

12 hours are many opportunities for a creative curriculum developer to make the links between the social and physical sciences and humanities.

The argument for inclusion of STS courses in community college curricula is relatively easy to make. The actual development and implementation of these courses, or even more broadly a total curricular approach, is much more challenging. Faculty members are narrowly educated themselves, and often feel uncomfortably challenged when asked to look at their disciplines in new ways. Accreditation and articulation agreements are frequently rigid. Considerable effort and commitment will be required for any significant change to occur. Proponents of STS in community colleges will have to make their case vociferously, in many fora, over an extended time.

One of the ways to make this case is panels such as the one represented by the papers that follow. Each, from a different perspective, describes the case for STS and one approach to either the deliberation about focus or actual program implementation.

CORRINNE CALDWELL is Dean of the Division of Mathematics, Physical Sciences and Engineering Technologies at the Community College of Philadelphia, 1700 Spring Garden St., Philadelphia, PA 19130.

Bull. Sci. Tech. Soc., Vol. 6, pp. 259-260, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

SCIENCE, TECHNOLOGY AND SOCIETY IN THE COMMUNITY COLLEGE

James C. Williams

Science, Technology and Society Studies (STS) began as a conscious discipline 15 years ago. By the mid-1970s, a Cornell University guide to the field reported some 400 institutions, 100 programs and 2000 courses dealing with STS.[1] Today , while not all the programs identified by Cornell continue to exist, STS remains a strong area of study in four-year colleges and universities. This unfortunately is not the case in community colleges.

The 1975 Cornell guide identified only 29 two-year colleges offering STS courses. In 1980 the Technology Studies and Education Committee of the Society for the History of Technology (SHOT) sponsored a survey of 820 public two-year colleges and received a 19 percent return.[2] It revealed only 39 colleges offering STS courses, three of which were two-year campuses of state universities and 16 of which had been listed in Cornell's study. None of the responding colleges offered what might be called an STS program.

The SHOT survey reported only 52 STS courses, some of these only vaguely related to STS. Thirty-five dealt with "science/technology and society," "environmental studies" and "history of science/technology." The rest were scattered offerings in philosophy, science, computer science, "future studies" and film classes using James Burke's "Connections" and Jacob Bronowski's "Ascent of Man" series. There were no common texts or audiovisual materials cited. The courses had a median enrollment of 25, half the courses were offered only once each year and 70 percent of them were elective courses.

More recently, at the 1986 National Technological Literacy Conference, two-year college teachers present generally agreed that STS continued to have only a toe-hold in community colleges. With the exception of an interesting program in appropriate technology and human ecology at Monroe Community College in New York, the types of courses seemed not to have changed significantly since the SHOT survey. They continue to hold an elective status outside the general education curriculum pattern and draw few students.

Community colleges seem to shy away from STS for a combination of reasons. Articulation is difficult between community colleges and the four-year institutions and universities to which so many of their students transfer, for the latter generally confine transfer credit to traditional "lower division" offerings. Four-year colleges and universities hardly provide curriculum development leadership to community colleges. There is a general tendency toward limited change in the liberal arts, general sciences and pre-professional studies programs, and in this situation an elective STS course, if offered, is assured slight enrollment.

Additionally, most community college instructors did not face STS coursework in their own educations, so their own experience mitigates against embracing STS in their teaching. Even where instructors would wish to implement courses, little time is available for the necessary professional preparation to develop them. Finally, a growing emphasis on "career training" programs in community colleges helps to stifle STS and other academic innovation. On the whole, community college curriculum seems governed by academic traditionalism.

One area of curriculum development in which community colleges recently have shown interest focuses on "technological literacy." Here, the potential of strong academic interest is found in the work of community college instructors in the National Science Teachers Association. But trendy courses such as computer literacy and those offering technological understanding for technical careers plus a movement to employ computer technologies to "improve" teaching dominate the community college landscape. Indeed, the aim of technological literacy does not appear to be the same as that of the STS field. Virtually nowhere does one find an effort in technological literacy courses to bring to the surface and carefully study the value judgments which drive society's science, technology and engineering decisions, yet this is the real purpose of STS.[3]

What should be done in community colleges concerning the STS field? Should it be avoided? More than one community college instructor familiar with the issue has argued that STS may not belong at the two-year college level. Community college students already have enough anxiety over the open endedness of truths and values, and STS may do more harm than good. Should it be embraced? Many others feel strongly that STS is too important to ignore. Definitions and values must be studied, and students must be prepared to live in a world continually facing important STS issues. They must face technological issues of varying character, from the value of appropriate technology and the impact of technological change on society and the environment to issues on the cutting edge of high technology.

In the end, it may be up to community college faculties and leaders to decide if STS is important enough to embrace. If the choice is the develop STS, faculty must vitalize it, administrators must fund it and insist on positive articulation with four-year colleges and universities. But leadership and support must also come from other quarters. Community colleges, which annually provide hundreds of thousands more Americans a higher education than all other institutions of higher learning combined, too often are relegated to second class status in academic innovation. If proponents of STS permit this to happen in their field, they surely will miss a marvelous opportunity. Worse, the majority of America's college students will suffer for it. Therefore leadership and support must come from four-year colleges and universities and from private foundations and federal programs such as the Carnegie Foundation, National Science Foundation and National Endowment for the Humanities. Only then will community colleges truly embrace science, technology and society studies.

Documentation

1. E. Heitowit, J. Epstein and G. Steinberg, Science, Technology and Society: A Guide to the Field (Ithaca, New York: Cornell University Program on Science, Technology, and Society, 1976).
2. J. Williams, editor and compiler, Science, Technology, and Society in Community Colleges (Gilroy, California: Gavilan College and the Society for the History of Technology, 1981).
3. Stephen Goldman offered this succinct definition of STS in comments at the National Technological Literacy Conference, Baltimore, 1986.

JAMES C. WILLIAMS is Director of the California History Center and Foundation at DeAnza College in Cupertino, CA 95014. He also serves as coordinating secretary of the California Committee for the Promotion of History and consults in cultural resource management studies and energy history with various government and news agencies and utility companies.

Bull. Sci. Tech. Soc., Vol. 6, pp. 261-267, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

STS IN THE COMMUNITY COLLEGE: THE HUMAN ECOLOGY PROGRAM AT MONROE COMMUNITY COLLEGE

M. Garrett Bauman and Robert H. Herzog

As the only community college in the nation with a comprehensive core of STS courses, Monroe Community College serves as a case study in the creation of such a curriculum and as a model for other two-year colleges.

The paper discusses the origin of Monroe Community College's curriculum (titled Human Ecology), some administrative and logistical considerations for survival, and then focusses on curriculum development in three basic areas: Spaceship Earth, Technology and Human Concerns, and Self-Reliance Skills. Over 400 students have enrolled in the eight new courses developed since 1983.

Science, Technology and Society education has fared poorly in America's community colleges. At present only a few two-year institutions have more than an isolated course or two. In fact, based on available resouces, we believe Monroe Community College is the only community college in the nation with a comprehensive core of courses dealing with STS issues. As such it might be useful to outline the development of Monroe Community College's curriculum, titled Human Ecology, as a case study and as a model for future community college involvement in STS.

In 1976 when a group of thirty faculty and administrators first gathered to discuss the shortcomings of our current liberal arts paradigm, we realized the latest "hot" courses--in computers, high technology, women's studies and others--barely scratched the surface of what a well-educated liberal arts or technical graduate from our college in the year 2000 should know.

We looked at the cancer scourge induced by various types of pollution, an exploitative approach to ecology and resources, one billion people living in absolute poverty, a one-hundred year count-down on the supply of fossil fuels, the erosion of individual rights and creativity amid increasing standardization, and hundreds of new technologies developed in a value vacuum. Then we looked at current college programs both at community and four-year colleges. Most Liberal Arts graduates seemed technologically illiterate, and most technical graduates saw ethics as irrelevant to their occupations. Current Liberal Arts programming seemed uncoordinated, not teaching students genuine self-empowerment. What were these students learning that could prevent the awful prediction of the famous Global 2000 Report to the President and others from coming true? Were they and their children doomed to a bicycle and rice economy, a faceless job in a mega-corporation, a world where human values and technology were mutually exclusive?

Our group thought these problems were not insoluble and sketched out a new community college liberal arts option that might better prepare students for the Twenty-first Century.

Funding

That, in essence, is what we said when a Task Force, headed by three divisional deans and including a dozen faculty supporters from ten different academic departments, approached The Fund for the Improvement of Post-Secondary Education (FIPSE) with a grant application. We had already held several public forums and created a very successful pilot course in "Global Interdependence," but we wanted a full-scale academic program to bring these early efforts to fruition. We asked for a three-year grant of $190,000 to pay for faculty release time (to develop and research courses, attend seminars, meet weekly, and create a truly interdisciplinary team) and to pay for alternative energy equipment (including an electric-generating windmill and solar collection devices), consultants and speakers, and secretarial support. Rejected once, the Human Ecology Project was funded on the second try from September, 1982 to August, 1985 (one of only 60 projects funded from a pool of over 2300 applying institutions nationwide in 1982). FIPSE hoped we would break ground and serve as a model for other community and four-year colleges.

This liberal arts program in Human Ecology is designed with rigorous requirements in Mathematics, Science, and Humanities so students can readily transfer to a variety of four-year programs in Liberal Arts and Sciences and is based on the premise that students must be aware of the ecological, ethical, and technological challenges facing a citizen of the Twenty-first Century. Our flexible instructional delivery system made the courses accessible as electives to full-time and part-time students in career and technical fields as well. Over 400 students have enrolled in the eight new courses offered over the past three years--a handful as Human Ecology "majors," but most as career or general Liberal Arts students.

The Curriculum

Monroe Community College's curriculum was developed from the assumption that as many courses as possible be given to existing departments rather than tossed into the limbo of interdisciplinary offerings (see Table 1). We felt this would improve transferability, offer many departments a stake in the program rather than threaten them with competition, and increase the likelihood of infusing Human Ecology ideas into other faculty members.

We were careful to distribute the core courses among the traditional liberal arts divisions so students could easily transfer to a four-year college and major in traditional fields. For instance, "Applied Energy Systems" is a natural science course (Physics), and "Health for Life," a four-credit course substitute for Physical Education, and a philosophy course like "Technology and Values," has become an important and relevant humanities elective for technical students.

It was important these courses be tools for students, not something that would hinder degree completion in other fields. The student graduates with an A.S. degree in liberal arts and sciences and may choose to emphasize the Human Ecology concentration, since there are no Liberal Arts majors in the New York community college system.

Program electives can be picked from among many courses at the college and are chosen with the advice of a Human Ecology professor, depending on the specific transfer or vocational plans of each student. For instance, a student hoping to work in environmental news reporting would be encouraged to take additional courses in public policy, biology, and journalism. A student hoping to transfer into a global studies program might be encouraged to take electives in politics, economics, and world health issues. A would-be entrepreneurial builder of solar additions would be encouraged to elect engineering, civil technology, and design courses.

Table 1
Liberal Arts and Sciences
- Human Ecology Concentration -

		Credit Hours
FIRST SEMESTER		
English 101	Basic College Writing	
	or	
English 200	Advanced Composition	3
*Philosophy 105	Technology and Values	3
*Humanities 110	Self-Reliance	3
*Geography 101	Physical Geography (with lab)	4
*Social/Behavioral Science 110	The Individual in Society	3
	Total	16
SECOND SEMESTER		
Mathematics 170	College Algebra	3
*English 106	Technology in Literature	3
*Biology 116	The Human Environment (with lab)	3
*Social/Behavioral Science 150	Global Interdependence	3
PROGRAM ELECTIVE		3-4
	Total	15-16
THIRD SEMESTER		
*Physics 122	Applied Energy Systems (with lab)	4
*Health Science 160	Health for Life	4
SOCIAL SCIENCE ELECTIVE		3
GENERAL ELECTIVE		3-4
PROGRAM ELECTIVE		3-4
	Total	17-19
FOURTH SEMESTER		
*Human Ecology 215	Human Ecology Practicum	3-4
*Mechanical Technology 230	Energy Efficient Home Design (with lab)	4
SOCIAL SCIENCE ELECTIVE		3
GENERAL ELECTIVE		3-4
PROGRAM ELECTIVE		3-4
	Total	16-19

*Core courses. Biology 116 and Geography 101 were existing courses.

In addition to courses in writing, mathematics, and a traditional distribution of electives, the curriculum has three basic components: courses studying Spaceship Earth, courses integrating Technologies and Humanities, and courses developing Self-Reliance Skills.

Spaceship Earth

The Spaceship Earth courses--"The Human Environment," "Physical Geography," and "Global Interdependence"--aim to develop awareness of global interconnections.

Many futurist researchers have predicted that if present trends continue, there will not be enough food, shelter, clean water, or raw resources for our overpopulated planet within the next 20 to 25 years. The Global 2000 Report prepared by President Carter's Council on Environmental Quality and the Depatment of State stated that we will almost certainly extinguish 20% of all our fellow species on the planet by the year 2000 through pollution and habitat destruction. The United States and the Soviet Union trade rain clouds every twelve hours while threatening each other with nuclear bombs; more people are malnourished today than would have populated the earth in 1950; more people will be malnourished in the year 2000 than populated the earth in the year 1940; Polish default reaches into the coffers of all banking nations; the existence of a global economy is accepted as fact by even the most isolationist politicians; and scientific breakthroughs (or the lack of them) mean survival or death for millions in the next decade. We think our students, who may become the managers of the next century, need the holistic perspective offered by these three courses.

It is important for students to understand that while some of these problems are excruciatingly complex, others simply require awareness or individual effort. As Dr. Amory Lovins told one Human Ecology audience at Monroe Community College in December of 1982, "the U.S. can become energy self-sufficient in five years--just by plugging holes and not driving petro-pigs." No persons in the year 2000--and all students born this year will enter college after the year 2000--will be educated without understanding the operating principles of Spaceship Earth.

"Physical Geography" emphasizes climate, resources and vegetation in relation to human activities. Students learn how man-made climactic changes affect soil fertility; they analyze what physical conditions allow safe off-shore oil development or the creation of a landfill, what problems a proposed shopping mall may cause, and the advantages and disadvantages of a particular site for a home.

"The Human Environment," a biology course, studies the interaction of ecology, pollution, radiation effects, and human beings. What dangers to North Americans are posd by jungle clearing in South America? How could the extinction of a rare species of fish or flower be detrimental to the future of the human race? What alternatives to current waste disposal methods are feasible today? What would a nuclear winter mean to worldwide ecology?

"Global Interdependence," a social science course, emphasizes the cultural, social, and ethical networks of planet Earth. This course makes students aware of how enmeshed their lives are with seemingly distant events--international energy exploitation and economics, global poverty, human rights, arms and food trade, nuclear weapons proliferation, and third world debt. A major thrust of the course is to think imaginatively about such solutions as grass roots initiatives, alternative energy sources, and appropriate technology. The course is team-taught by social science, biology, and English professors.

Technology and Human Concerns

In addition to studying technology in a recommended computer course and taking the required courses in shelter and energy (discussed below), students must also take three courses that relate technology to human concerns: "Technology and Values," a philosophy course; "Technology and Literature," an English course; and "The Individual in Society," a social science course.

These three courses provide the philosophical center for the program. Future education must examine the nature of technology and its influence on our sense of what it means to be human. For, on the one hand, technology offers unimaginable potential and, on the other hand, creates the possibility for barely imaginable horror, yet little has been done to understand the meaning and implications of technology. Much has been said about "its" effects, as if technology were a monolithic entity, but little study has been devoted to technology's multifaceted nature. These three courses, then, provide the student with an opportunity to understand the difficulty of defining technology, and to learn how to assess critically the types of technology most appropriate to one's sense of what makes life worth living. Though valuable in and of itself, this study is crucial to our program, which emphasizes the importance of individual analysis and choice based on that analysis.

These courses allow students to examine how human values are implicit in the various technologies we adopt. The Appropriate Technology movement, for instance, says human values are best served by technology that is small-scale, diverse, easy to fix and understood by its owner, and that uses renewable energy; current governmental attitudes, on the other hand, hold to large-scale, centralized technologies that are understood by experts and consume vast amounts of nonrenewable energy. While there are natural biases on the part of the instructors, the intention is not to sell one system over another, but to help students arrive at their own definition of the good life and evaluate and select technologies most likely to lead to that good life. The courses discourage simplistic attitudes that would condemn or praise any technology (whether it be high-tech or low-tech, large or small scale) without carefully considering life objectives.

Concepts shared by the three courses include the following: defining "technology" and "the good life"; understanding the conflict between individual freedom and the social contract; and the importance of conscious choice over blind acquiescence.

In "Technology and Values," students study historical relationships between values and technological developments. They learn how values are acquired and how to make reasonable judgments about emerging technologies, thus developing their own philosophies of technology. One aspect of the course is a semester-long project on values clarification dealing with plans to develop a hypothetical marsh. Students are assigned to groups having competing interests and must research and debate to determine whether the marsh deeded to a town is to be used for recreation, ecological research, or for a factory that will supply needed employment for the town.

"Technology and Literature" uses mainstream literature from the past and present to analyze the influences of various technologies on such values as freedom, social responsibility, and the imaginative impulse. Which technologies expand and which enslave human capability, for example? One aspect of the course treats language as a technology, so technology is studied as both form and subject in poetry, fiction, and expository prose. Films such as 2001: A Space Odyssey are used to explore literary themes and to reveal how technology as an art form enhances humanistic study.

"The Individual in Society" studies the impact of technology on fundamental aspects of humanity such as biological imperatives, social change, individualism, and freedom. Tracing the historical background of our modern sense of "individualism" is a major part of the study, as is the psychology of personality structure and development. One course unit enables students to determine their stylistic approaches to value clarification and decision-making through computer-assisted and other self-assessment exercises.

Self-Reliance Skills

To apply ecological/global awareness and theories about technology and values concretely, students take five hands-on self-reliance courses, perhaps the most innovative aspect of our liberal arts curriculum.

"Health for Life" teaches students how to doctor themselves more effectively, emphasizing wellness and prevention. Using holistic approaches tying body, mind, and spirit together, students investigate traditional medical techniques as well as such alternatives as relaxation, vegetarianism, meditation, and accupressure.

"Applied Energy Systems" examines the physics of energy and applications to individual energy self-reliance: woodstoves, biogas units, wind generators, solar photovoltaic systems, and solar heating. Students study design, economics, and efficiency and get hands-on experience installing and monitoring alternative energy devices.

"Energy-Efficient Home Design," a mechanical technology course, teaches students how to design and build a home from drawings to foundations to roof shingles. We emphasize energy, economic efficiency and hands-on practice. As part of the class, Monroe Community College students have built a heavily insulated, pole-foundation sunspace on the campus. Project faculty and students held two old-fashioned house-raising parties to give the classes a boost. The 800-square-foot building will house human ecology classes and be a center for ecology on campus. Electricity will be provided by three photovoltaic panels and our one-half KW wind generator, while an efficient woodstove will provide backup heat for Rochester's cloudy Januaries.

"Self-Reliance," a humanities course, combines theories and philosophies of self-reliance from Thoreau to Scott Nearing with hands-on skills. Students have built cold frames, a loom, solar collectors, a dome greenhouse, organic gardens, food dehydrators, and insulating window shades. One student wrote and performed his own play; another conducted her own divorce suit without a lawyer. There have been foraging expeditions, class barter sessions, creative recycling projects, and meatless cooking demonstrations. We have found students are more creative when they explore knowledge they want to have. In conjunction with practical problem-solving, students develop a personal philosophy of self-reliance by writing "position papers" on topics like possessions, work, death, and nature as teacher.

Last, a student enrolled in the concentration is also expected to develop an independent study project or work as an intern (the "Human Ecology Practicum"). Members of our community advisory committee try to offer positions: reporting for a local environmental newspaper, assisting an organic farmer, or working with a solar architect.

All the self-reliance courses stem from Emerson's ideal of the practical scholar as expressed in his "American Scholar" essay. Emerson reminds us a scholar must take knowledge from three sources: Nature, Books, and Action--and not just from books, or, as he said, "instead of Man thinking, we get the bookworm." The self-reliance courses also suggest concrete answers for the resource and ecological problems raised by the Spaceship Earth courses and for the threats to freedom and ethics raised by the technology and values courses.

By learning to rely on themselves more students quell the spectre of 1984's Big Brother. By avoiding central control of food and energy supplies, they increase individual empowerment. Awareness of conserving lifestyles also reduces the drain on world resources. We hope that by emphasizing outwardly simple and inwardly rich lifestyles we will contribute to the quality of our students' lives so that life is not merely done to them as is too frequently the case. Our not-so-disguised moral principle might be stated this way: a person pays his way in life by what he is or does, not by what he has.

Conclusion

Monroe Community College's experiment with an STS curriculum has proved there is a "market" for such a program in the community college. We have had to cancel only one class in three years, and with a small core of dedicated "majors" and the larger pool of students who sample a few Human Ecology courses, it seems clear now that we will sustain current offerings. Career-oriented, younger students are sometimes intimidated by the self-sufficiency we encourage and do not always see job potential in Human Ecology, but for others--mainly older students returning to college--Human Ecology has been a great revitalizing opportunity. In the past two years we have had inquiries from over fifty institutions worldwide and have done some intensive follow-up/consulting with two-year schools in New York, Michigan, and California. We think it likely that in the future other community colleges will join us.

References

Gerald O. Barney, Study Director. The Global 2000 Report to the President (Penguin Books, NY, 1982), pp. 1-44.

M. GARRET BAUMAN is Coordinator of Human Ecology and ROBERT H. HERZOG is Professor of English at Monroe Community College, 1000 E. Henrietta Rd., Rochester, NY 14623-5780. They have lectured and written extensively on STS subjects for both academic and general audiences.

Bull. Sci. Tech. Soc., Vol. 6, pp. 268-275, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

LEARNING AT THE INTERFACE: DOING COMMUNITY COLLEGE STS EDUCATION AS IF TOMORROW REALLY MATTERED

Neal A. Norris

> *Though there is a higher and wider significance to life, of what value is our education if we never discover it? We may be highly educated, but if we are without deep integration of thought and feeling, our lives are incomplete, contradictory and torn with many fears; and as long as education does not cultivate an integrated outlook on life, it has very little significance.*[1]
>
> Jiddh Krishnamurti, 1953

> *All education springs from some image of the future. If the image of the future held by a society is grossly inaccurate, its education system will betray its youth.*[2]
>
> Alvin Toffler, 1974

The Problematic Situation of Today and Its Resolution

The modern era is often characterized as a turning point, transformation, or breakpoint which has occurred only one or two times previously throughout history. Our era is compared to the great transition from nomadic existence in paleolithic and mesolithic times to agricultural existence during the neolithic era, and to the transition from the neolithic agricultural village to urban civilization around 3000 B.C.[3] Many futurist thinkers argue that the current transitional era is a unique and critical phase of human development. Successful navigation of this period depends on a fundamental restructuring of individual and societal values within a very short period of time. Otherwise human catastrophe is quite probable if not inevitable.

The achievement of the current stage of socio-cultural development requied the acceptance by almost all Western societies of a world-view (and image of the future) built upon positivistic naturalism validated through empirical science.[4]

A consequence, recognized by many futurists, is that humanity now has the power to destroy itself physically and spiritually; most also recognize the fragility of the biosphere. The concept of the interdependence of ecosystems has been transferred to the arena of human relations throught the emphasis placed on the interdependence of the numerous races and national states throughout the world.

A second consequence of Western humanity's increased technical capacities, especially in communications, transportation, production, and biochemistry, has been the sharing of certain historical experiences and trends. Two world wars and the Great Depression highlight global trends toward increased industrialization, urbanization, Westernization, institutional bureaucratization, technical sophistication, and socialization of education and war.

These developments have led to the recognition that the meaning of the human condition must now be reconsidered. While many futurists would accept much of this description of the global situation, they would emphasize different reasons for its occurrence and promote various means of successfully reaching the next stage of socio-cultural development.

Scientific-Technical vs. Visionary Alternatives Futurists

Scientific-technological futurists take an approach to the future emanating from a control and management orientation. They seek to ease the stress and dislocation generated by the present situation by controlling future events through the use of sophisticated forecasting techniques integrated by a comprehensive cybernetic systems theory. While recognizing that the technological applications of various scientific discoveries have had some significant detrimental consequences, scientific-technological futurists, such as Herman Kahn and Daniel Bell, remain faithful to the essence of the prevailing Western world-view. They presume that the solution to whatever problems are caused can be found by creating newer, more potent technologies. Social futurists (the activist arm of scientific-technological futurism) such as Alvin Toffler, employ a democratic decision-making model based on systematic anticipation of potential problems and wide participation in their resolution.

Visionary-alternatives futurists like Theodore Roszak and William Irwin Thompson use a wide variety of heuristic approaches as a way of creating rather than controlling the future. Images of the future are of great importance to these futurists, especially those images embodied in adapted versions of general systems theory and in the various spiritual fusions of science and art.

Scientific-technological futurists and visionary-alternatives futurists do, however, hold different views of the meaning of technology and its relation to the nature of change and educational purposes. For scientific-technological futurists, the nature of change is societal before it is individual and is based on the processes of incremental accumulation of knoweldge and technological diffusion, to which individuals must adapt. Visionary-alternatives futurists, on the other hand, emphasize the primacy of being over process, and assert that the nature of change is individual before it is societal and is grounded on the transformative nature of images, knowledge, and human consciousness. The individual person remains central with inherent dignity, meaning, and value. For scientific-technological futurists, societal change occurs mainly as a result of quasi-autonomous technological advance which forces cultural adaptation. Most visionary-alternatives futurists, however, believe societal change occurs as a result of the interaction of technological, cultural, moral, spiritual, and evolutionary forces.

The chief engineer of change for scientific-technological futurists is techno-economic development based on a form of systems thinking that relies heavily on sophisticated planning and management techniques to obtain ever greater control over the physical world and to mitigate whatever unintended developmental consequences may occur. Transformative evolution remains the primary propulsive force of change for the visionary-alternatives futurists; and their basic philosophical focus moves beyond the forms of knowledge accepted by the scientific-technological futurists. Physical realities are often felt to express metaphysical dimensions and these are often linked by using some form of general living systems theory (holonomy) in a cosmic, evolutionary manner.

Though most members of both wings of the futurist movement seem to accept the accelerating rate of technological change, the scientific-technological futurist believe the magnitude and scope of this acceleration is exponential, following the pattern of an algorithmic curve, while many visionary-alternatives futurists suspect the rate of change is not exponential but may slow down in the future, conforming to the pattern of an S-shaped curve.

Finally, the character of future technology is substantially different for each group. Most scientific-technological futurists envision various intellectual technologies founded on the primacy of theoretical knowledge and problem-solving techniques within a larger systems science. The primary pattern will consist of integrative, large-scale energy, communications, and transportation technologies. Visionary-alternatives futurists, however, assert the primacy of spiritual technologies based on the holistic integration of science, art, and religion reflecting appropriate and human scale within a larger general systems framework that is often evolutionary in nature.

The Futurists on Knoweldge and Education

Although most recent critics agree that education in the 1980s is beset by a number of unprecedented conditions, these same critics have substantially neglected two critical aspects of the futurist rationale in their thinking: the pivotal importance ascribed to knowledge and to education.[5] Daniel Bell, Herman Kahn, and other scientific-technological futurists have defined education instrumentally and understand it primarily as "intellectual technology." The chief purpose of education for these futurists is to mediate the creation, legitimization, and transmission of increasingly theoretical and technical information among knowledge elites within government, business, the military, and academe. Education should prepare the required number of systems engineers, technicians, planners, and global citizens to fill the highly specialized, meritocratic occupational system of a technology-laden post-industrial society. Knowledge and occupation would be mediated through the system of education, and a large portion of the burden would fall on the universities.

At the end of his introduction to The Coming of Post Industrial Society, written in 1973, Daniel Bell disclosed the real purpose of his work:

> *What I am arguing in this book is that the major souce of structural change in society--the change in the modes of innovation in the relation of science to technology and in public policy--is the change in the character of knowledge: the exponential growth and branching of science, the rise of a new intellectual technology, the creation of systematic research through R and D budgets, and, as the calyx of all this, the codification of theoretical knowledge.*[6]

The implicit one-dimensionality of education within the post-industrial society described by Bell and Kahn was vividly depicted by Peter Drucker in an exquisite historical analogy:

> *There is a horrible example in history of what the Educated Society might easily become unless the university commits itself to the education of the whole man. It is the destruction of one of the world's greatest and most creative civilizations, the China of T'ang and Sung periods, by the imposition of a purely verbal, purely intellectual, purely analytical education on man and society, the Confucian Canon. Within a century, this commitment to the purely intellectual in man destroyed what had been the world's leader in art as well as in science, in technology as well as in philosophy. We are today in a similar danger--for we, too, tend, under the impact of the triumphs of organization and of the analytical mind, to downgrade everything that is direct, immediate and not verbal.*[7]

Knowledge and education are also fundamental in visionary-alternatives futurist thinking. Most of these futurists view knowledge as evolutionary rather than accumulative, and define education as broadly transcendent. Its over-riding purpose is to promote individual and societal transformation. Education would link physics to metaphysics and create a new epistomological paradigm.[8]

Though very different views concerning educational purposes, structures, and strategies are depicted, the fundamental importance of education as a basic means of negotiating the current transitional era and closing the gap between our tchnical capacities and our cultural understanding is adopted by many futurists in both wings of the field. Futurists have questioned a multitude of educational practices and provided a fundamental challenge to transform education. This challenge is comprised of five characteristic features: (1) a definition of education that moves beyond the confines of conventional schooling, (2) reconceptualized organizational patterns, (3) a reformulated curriculum, (4) a new configuration of instructional methods, and (5) the infusion of available and emerging technologies.

Futurists often argue that the imperialism of formal education--perpetuating a cluster of practices based more on tradition and conventional wisdom than on solid research and evaluation--has shackled education to parochial interests and obsolete mythologies. Futurist educators contend the traditional institutional context of education composed of conventional schooling arrangements organized in age-graded structural and curricular patterns, is obsolete in advanced industrial societies.

Futurists also point to the lack of options within the conventional system as a fundamental weakness. Since the structure, content, methods, and results of the current educational enterprise are obsolete, these cannot help but be unresponsive and insensitive to the needs of individuals, communities, and the species as a whole. They argue that revolutionary developments in electronics, fiberoptics, lasers, communications, data processing, and bio-genetics will force a tremendous expansion in how education is conceived. Soon it will span all ages and will be decentralized in space and time to permit diverse organizational patterns that meet individual needs.

The move from conventional schooling arrangements to life-long living-learning systems responsive to individual needs and concerns should begin immediately futurists argue. This educational transformation requires new organizational patterns and expansion of the legitimate ways of learning. It will be mediated by potent new electronic, bio-genetic, and medical technologies (i.e., silicon-based systems such as sophisticated robots and thinking androids, synergistic human computer symbiosis, genetic transformation of the brain and of human nature and anti-aging and memory enhancement pills).

Futurists contend these emerging technologies should be introduced into education as one way of transforming the structure of schooling. Computer-assisted, managed, and mediated learning should be encouraged, as should two-way, interactive television, micro-computers, and other silicon-based systems. (Unfortunately, most educational futurists have failed to question the controlling assumptions implicit in calls for such wholesale application of emerging technologies within educational settings, and community college educators have been even more lax in this regard.) In short, futurists have presumed that the contemporary constitution of American education at all levels is irrelevant, anachronistic, and obsolete when viewed in relation to emerging global realities and critical transitional concerns.

The necessary refiguration of education ideally requires a simultaneous assault on educational theory and practice, which some futurists believe can occur. Others have adopted a more pragmatic transformational process in which (1), all aspects of the primary educational institutions, that is, the school districts, community colleges, and universities are substantially reconstructed, and (2) these conventional institutional and organizational patterns are then transcended on the way toward developing decentralized, individualized, life-long living-learning systems. Key aspects of this process include greater community participation, increased programmatic options, and humane recognition and humanistic application of selected educational technologies to enhance the decentralized, participatory, individualized features that should characterize life-long learning in a communications-era society.

Implications of Futurist Thinking for STS in Community Colleges

Futurist educators like Alvin Toffler, Harold Shane, Ronald Barnes, Donald Glines, James Bowman, Christopher Dede, Frederick Kierstead, and John Pulliam have prescribed various remedies for our critically ill educational system. These futurists view education as a central, essentially transformative agency within society. Although the scope of this paper does not allow a comprehensive presentation of their educational prescriptions, each has recognized the unique position and potential of community colleges within an overall living and learning system, and these should be studied in detail.[9]

Obviously, scientific-technological futurists and visionary-alternatives futurists perceive the role of technology and its relation to education differently. Futurist educators seem to have incorporated elements from both wings of futurist thinking and from existing educational reform positions (e.g., social reconstructionist, liberal-consensus, neo-Marxist revisionist, neo-Romantic revisionist, and anti-technicist) into their own thinking about educational alternatives. They rely on appropriate use of selected, emerging educational technologies to assist educators and learners alike in reducing the gap between our technical capacities and our cultural understanding.

Future criticism of contemporary American educational theory and practice indicates that significant changes are required to provide relevant learning opportunities to today's students. Futurist educators have created several prescriptive models that provide appropriate alternatives to present educational practices. Each model is designed around new ways of understanding the inter-relationship of knowledge, learning, and technology.

Most proposed alternative learning systems also include a substantially reformulated curriculum design reflecting the characteristic features of the larger system. Futurist educators would, for example, reverse the prevailing emphasis on scientific and technological approaches to curriculum-making. They often emphasize seven characteristic features of an effective educational program; these are especially important to community college educators. First, it should provide several options to the conventional educational program. Second, it should span traditional disciplinary boundaries. Third, it should focus on, and respond to, critical problems of the real world. Fourth, it should be concerned with the imagination, design, and realization of alternative futures as well as understanding of the present and past. Fifth, it should include global and cosmic as well as local and national perspectives. Sixth, it should emphasize ways of learning rather than strategies of teaching. And seventh, it should be sensitive to individual needs and be concerned with the exploration, realization, and expansion of human potential.

Given the prescriptive directions of futurist educators and current educational refort efforts, the timing of science, technology, and society program initiatives is fortuitous, especially for community, junior, and technical college practitioners. A time of critical re-examination of education at all levels is underway, as the crippling covert curriculum of industrial-era schooling described by Alvin Toffler in 1974, and based on such values as punctuality, obedience (excluded knowledge), rote work, productivity, efficiency, and linear-extrapolative thinking, is becoming more anachronistic each day. At the same time, the multiple choice awareness fostered by elaborate, competitive systems of grading, tracking, and promotion has long since become obsolete.

Two-year colleges also confront sweeping demographic, economic, political, and technical changes--the cumulative effect of these will force a fundamental re-thinking of college missions, financing, governance, and instructional programming, as has already happened in Maryland, California, Florida, and several other states. Though very few community college science, technology, and society program options currently exist, the climate on campuses and in statehouses is promising.

Historically, American two-year colleges have embraced three distinct conceptions of themselves. The first, or junior college conception, envisioned the two-year college as a place for area students to complete the first two years of baccalaureate degree work (the transfer function). The next conception which emerged, that of the technical college, incorporated a view of the college as a place to obtain entry-level occupational and semi-professional training (the technical-occupational function). The most recent conception of the two-year college coalesced around the notion of community service. The college, in this view, would provide diversified programming for non-traditional learners, area businesses, and local professional groups (the continuing, adult, and external degree function).

New perceptions of alternative two-year college missions are now being created as state-wide task forces, state legislatures, and sponsoring entities deliberate on ways to reorganize community college systems in light of dramatically changing educational, social, political, and economic realities. One holistic view conceives of community colleges becoming future-oriented community learning systems, comprehensive learning networks integrating the three previous views, using the future as an organizing conception throughout the curriculum, and focusing on personalized, option-oriented learning and community impact, as many futurist educators suggest. Regardless of what conception is finally chosen, however, the need for creating stand-alone science, technology, and society program options or integrating technological literacy throughout the community college has never been greater.

What Is to Be Done?

The general futurist rationale, educational critique, and selected prescriptions should offer a unique perspective from which to consider the unprecedented opportunities now available to community college educators. Today, we confront an educational challenge greater than that of the early decades of the 20th century. In 1900, American colleges and universities enrolled only about 200,000 students; in 1981 almost 10 million people--more than one-third of whom were over 25 years of age--registered as students within institutions of higher education, and more than one-half of these attended two-year colleges.

The traditional configuration of higher education in the United States is also changing dramatically. American business and industry have become heavily involved in their own massive educational and training efforts, spending between 80 and 100 billion dollars a year. American Telephone and Telegraph alone spends more than 1.3 billion dollars on employee training, and a massive market for full-time and part-time educators has opened in these areas, providing approximately 700,000 new teaching positions.

As "sunset" industries, such as steel, shipbuilding, textiles, and automanufacturing fade from predominance, efforts to retrain laid-off workers and obtain those with the new skills required by the "sunrise" industries (i.e., computer, electronics, telecommunications, aerospace, pharmaceutical, bio-genetic, etc.) will escalate significantly. The stakes are global and the programmatic options community colleges devise and initiate will substantially determine the effectiveness with which our society will negotiate the current transitional epoch.[10]

Educators and their institutions, at all levels, are being challenged by students, parents, politicians, and business people alike to create better places of teaching and learning. To be better, however, means we must do community college education as if tomorrow really mattered. We must re-think the ways in which community college education is conceived, organized, and transacted. Perhaps the great social planner, William F. Ogburn said it best in 1935 when, speaking of the reconstructive power of education, he forged this simple syllogism: *"If, (a) the future is to be different from the past, and if (b) we are to live our lives in the future, then (c) we ought to educate for a changed future--one different from the present or past."*[11]

To accomplish this, we must do at least this much:

1. We must unlearn the conventional controlling assumptions and predominant configuration of 20th century higher education.
2. We must devise an option-oriented community college curriculum that provides a dynamic balance among the humane arts and occupational studies, and non-traditional learnings.
3. We must construct multi-dimensional approaches to learning and teaching that are sensitive to diverse ages and needs of our students and colleagues.
4. We must emphasize specific areas of strength, including capacities to provide enhanced accessibility to--as well as appropriate opportunities for--continuing, life-long learing.
5. We must seek a shared sense of educational purpose and vision grounded in a more comprehensive understanding of our present position in history and of the power of the futures imagining capacity as it relates to human choice.

As community college educators and citizens, our goal could then become the creation of a true future-oriented community learning system--one which included as a matter of course such characteristic features as long-range planning, comprehensive professional support services, option-oriented ways of learning, and an educational agenda that encouraged a fundamental understanding of technology and its relation to the significance of life.

References

1. J. Krishnamurti, Education and The Significance of Life (Harper and Row, San Francisco, 1981).
2. A. Toffler, Ed., Learning For Tomorrow: The Role of The Future of Education (Vintage Books, New York, 1974).
3. K. Boulding, The Meaning of The Twentieth Century (Harper and Row, New York, 1965); and F. Polak, The Image of The Future (Jossey-Bass, San Francisco, 1973).
4. H. Smith, Teachers College Rec. 80 (1979); and H. Smith, Teachers College Rec. 82 (1981).
5. The relative status accorded empirically grounded technical knowledge or spiritually grounded imaginative insight has provided the epistomological cornerstone on which many elements of the futurist rationale are often constructed.
6. D. Bell, The Coming of Post-Industrial Society: A Venture in Social Forecasting (Basic, New York, 1973), p. 44.
7. P.F. Drucker, The Revolutionary Theme in Contemporary America, T. Ford, Ed. (n.p., Lexington, 1965), pp. 93-94.
8. See W.I. Thompson and T. Roszak. Also M. Berman, The Reenchantment of The World (Bantam, New York, 1974); F. Capra, The Tao of Physics (Shambhala, Berkeley, 1975); F. Capra, The Turning Point: Science, Society, and The Rising Culture (Bantam, New York, 1983); and K. Wilbur, Ed., Quantam Questions: Mystical Writings of The World's Great PHysicists (Shambhala, Boston, 1984).

9. See A. Toffler, Ed., Learning for Tomorrow: The Role of The Future in Education (Vintage, New York, 1974); H.G. Shane, Curriculum Change Toward the 21st Century (N.E.A., Washington, 1977); H.G. Shane, The Educational Significance of The Future (Phi Delta Kappa, Bloomington, 1973); R.E. Barnes, Design Strategy Statement on Education, Preliminary Report (n.p., n.p., 1973); R.E. Barnes, Learning Systems for the Future (Phi Delta Kappa, Bloomington, 1972); D.E. Glines, Educational Futures III: Change and Reality (Anvil Millville, 1978); and J. Bowman, F. Kierstead, C. Dede, and J. Pulliam, The Far Side of The Future: Social Problems and Educational Reconstruction (n.p., World Future Society, 1978).

10. J. Botkin, D. Dimancescu, and J. McClellan, Global Stakes: The Future of High Technology in America (Ballinger, Cambridge, 1983).

11. W.F. Ogburn, The Social Frontier I (1935).

NEIL A. NORRIS is Coordinator of Curriculum and Professional Development at Reading Area Community College, Reading, PA 19603. He currently serves as Chairperson of the Future Trends Commission of the National Council of Staff, Program and Organizational Development, an affiliate council of the American Association of Community Development.

Bull. Sci. Tech. Soc., Vol. 6, pp. 276-281, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

TO START AN STS COURSE IN K-12 SETTINGS

Robert E. Yager

Moves to STS (science-technology-society) are to be noticed throughout the U.S. These moves follow similar efforts in other countries--perhaps most noteworthy are the two U.K. national efforts: Science in Society and Science in a Social Context. Both of these programs are endorsed and promoted by the Association for Science Education in the U.K.; both have received much international attention.

Much attention in the U.S. was directed to the NSTA Position Statement entitled "Science Education for the 80's." In this paper the STS movement was given focus by the following statement:

> *"The goal of science education during the 1980s is to develop scientifically literate individuals who understand how science, technology, and society influence one another and who are able to use this knowledge in their everyday decision making. Such individuals both appreciate the value of science and technology in society and understand their limitations."*

The statement was followed with a list of characteristics that a scientifically literate person would possess--presumably after experiencing an STS-type of program.

The move to STS was given further impetus by the NSB report: Educating Americans for the Twenty-First Century. The curriculum input paper for this document called for a required STS course sequence in grades 9 and 10. This document is credited with initiating a reversal in terms of public interest in and and support for science education in the U.S. The Science Education Directorate was re-established and major funding was available early in 1984. Significant funds have been provided for development, evaluation, and teacher enhancement in the STS arena.

Several states have now mandated STS courses. Unfortunately change as a result of mandate is often change with mixed blessings. Many tend to change in name only; some make only minor moves; most miss the reason for the mandate. Nonetheless, efforts in such diverse states as New York, Pennsylvania, Wisconsin, and Utah have progressed to such an extent that STS moves can now be seen as something more than a dream of some national leaders.

Unfortunately, there is not general agreement on the meaning of STS approaches, courses, or materials. Professor E. Joseph Piel, head of a Technology and Society Department in the College of Engineering at Stony Brook, was one of the architects of an STS-type course in the late 60's--i.e., The Man-Made World. Piel was chosen to head the Project Synthesis STS focus group prior to 1980. Project Synthesis was a major NSF research effort which sought to study (synthesize) the current situation (critical reports, written source materials, new discoveries in science and education, futurist reports, and other written maTerials) to describe ideal K-12 science programs. After two years of effort, Piel's STS group defined the area as follows:

> *"A list of topic areas is commonly identified to describe the domain of STS. These are not the only topics that could be listed; however they do exemplify the kinds of issues which characterize STS. These areas are:*

Energy
Population
Human Engineering
Environmental Quality
Utilization of Natural Resources
National Defense and Space
Sociology of Science
Effects of Technological Development"

Immediately after the completion of the Project Synthesis report, NSTA initiated its Search for Excellence in Science Education (SESE) Program. NSTA utilized the ideal state descriptions from Project Synthesis as the criteria for excellence for the searches. Simultaneously, NSTA organized a series of expert task forces to begin new syntheses of information that would result in new ideal state descriptions, i.e., new criteria for defining excellent science programs. Several task forces were concerned with STS, namely environmental science, energy education, and STS revisited. The STS revisited effort was one requested by state science consultants--another indication of the great interest in and moves toward STS in U.S. schools.

The new NSTA abbreviated criteria for STS programs provide additional specificity for those contemplating STS efforts. This second task force which focused on STS indicated that STS programs must

1. provide opportunity for students to compare and contrast science and technology;
2. include examples of how scientific and technologic knowledge is acquired and used by individuals and by society at large;
3. provide a global perspective of the interactions of science and technology with societies;
4. present knowledge in the context of day-to-day experiences and related to the lives of the students;
5. introduce decision-making strategies and provide opportunities to use the strategies in reaching decisions related to STS issues;
6. include "solid" scientific and technologic content (facts, laws, theories, and simplifying assumptions);
7. provide students opportunities to learn various ways to access and disseminate information related to the decision-making process;
8. be the responsibility of a team involving teachers of various disciplines as well as members of the community;
9. employ different instructional strategies to provide the most effective exposure to the values, ideas, thinking, reasoning patterns of others including peers, adults, and experts;
10. foster development of creative and aesthetic awareness through learning experiences that motivate students to explore values, emotions, data, and skills related to specific events;
11. make full use of a range of instructional strategies;
12. use evaluation techniques which reflect the broad range of skills and knowledge students are expected to develop.

Part of the NSTA SESE program is the preparation of monographs elaborating on the criteria, descriptions of approximately ten exemplary programs from across the U.S., and an analysis of how these programs meet the criteria as well as areas where additional work is needed, assuming that no programs match the criteria exactly. In addition to the descriptions in NSTA's Focus on Excellence series, many of the persons involved with the development of the exemplary programs have been involved with Honors Workshops, presented papers, been featured on convention programs, and involved with television taping. Program models exist; teaching strategies necessary for successful STS programs have been devised; evaluation of STS programs has been undertaken; implementation strategies have been recorded and studied.

STS programs have some common features. They are all organized around problems, i.e., social issues. The problems and issues tend to be smaller and more local for the lower grade levels. At times global problems become the focus for secondary school efforts--at times curring across several curricular areas in the school. Many argue that the second "s" in STS is in reality the starting point. It is society in which problems/issues are identified. People make up societies. In one sense current issues provide an important way of making school, course content, science relevant to each student.

The content is not something that exists to be mastered. Instead the content unfolds; it is the ingredients, the factors, the necessities for dealing with given issues. The teacher does not identify content with the assertion that it will be useful. Instead students encounter the need to know. Basic to STS courses is this reversal in the position of traditional science content and the teacher's position to it. Science information becomes useful, a source of power, something to be identified and attained--as opposed to a given to be first mastered and then, if there is time, used.

The teacher's role in an STS program is drastically different than it is in a traditional science course. The teacher is not the person to identify specifically what text to use, what concepts must be learned, what order text and concepts will be considered, what is "passing" work, who should be encouraged to study more science. Instead the teacher gets students involved in locating information--both from written and human souces. Hopefully (probably) such information will be conflicting. This is why issues are issues--dealing with them is often not easy, surely not clear-cut. Less class time is spent with recitation; more class time is spent with debate and analysis.

In an STS classroom students must help prepare materials; they become important workers in terms of locating source materials, finding experts, taking positions, serving as detectives. In many situations there is more cooperative planning, working, and assessing. The classroom is a place where experiences are provided, give and take occurs, work on the resolution of issues takes place. Teachers can often profess not to be the expert--not to know the answers--not to be the taskmaster. Instead the teacher becomes a facilitator, an organizer, a leader, an arbitrator, a guide. Teachers must deal with a variety of persons--in addition to the students enrolled in a given class. The teacher makes suggestions, encourages student interchanges, helps establish criteria for making decisions.

Evaluation becomes less a matter of what information students can recall. In a traditional situation, teachers evaluate students primarily upon their ability to recall what is in the text, what was discussed in class, or what was done in the laboratory. Occasionally, students are expected to solve problems--usually almost exactly like those solved in practice. In an STS class students are evaluated on their ability to use information, their ability to act. Evaluations focus upon students and their ability to use high-level thinking skills, including analysis, synthesis, valuing. It is assumed that knowledge and simple science skills--such as the ability to explain, generalize, and even interpret--exist if students can perform at these higher cognitive levels. The focus of these higher levels suggests that inappropriateness and the problems with any focus on low-level skills. Such a focus causes students to develop a false sense of ability in science--almost an anti-science outcome, i.e. that science is the recall of specific information, including specialized definitions, formulae, and simple laws.

Students in STS courses have not scored higher on standard achievement measures. However, the learning that can be illustrated is learning that lasts longer over time. Presumably this is because the knowledge arises from direct experiences on the part of the individual students as well as on the part of the students in a given class as a social entity.

The standard measures of achievement are not the only type of interest when assessing STS courses. Students score higher on measures of decision-making; they have significantly better attitudes about science, science teachers, science courses, and the value of science. Studying STS courses results in more student involvement in the school, in the community; there is far more effective citizenship training; there is more interaction across the school in terms of other courses/teachers/departments/the administration. Parents become more involved as well as a great variety of other adults in the community. STS courses make the school into more of a microcosm of the community as a whole.

Critics of STS approaches often state that STS is not "science." Rustum Roy's S-STS project suggests that STS is an improtant way to get people "to" science. Still others argue that starting with science is to begin with abstractions, vocabulary, concepts, ideas that are far too complex and too far removed from the reality of most--certainly those who have not reached such higher stages of cognitive development. To be sure many students can learn by rote--they can learn to repeat information without any real understanding. STS materials and approaches may indeed be one way of getting more people "to" science. However, this goal of getting more people--by hook or crook--to the bodies of knowledge that we call biology, chemisry, physics, and earth science may not be a worthy goal at all. Perhaps it is a vanity to think STS provides but one more way of getting more people to science--just because getting them to science is inherently good. Is there any real evidence that persons who know science in a traditional sense do live a better life? Is getting all persons "to" science a goal of education? Does getting "to" science mean we have succeeded in making students scientifically literate? Perhaps we need to review NSTA's list of features of a scientifically literate person; then we need to examine traditional textbooks and/or course outlines to determine just what there is in the traditional program that could help produce learners with such characteristics. Then we should review some STS courses and teaching strategies. The comparison is striking; the activities that comprise student experience are related to the descriptions for a scientifically literate person.

During June of 1985 nearly fifty of the nation's most successful science teachers met at Phillips Exeter Academy in Exeter, New Hampshire. They were unanimous in their identification of the serious problems in school science. The major problem was the lack of curriculum structure to meet to the stated objectives--i.e., the real needs of students. The conferees were also unanimous in their insistence that all science teachers begin in the preparation of some STS materials and the use of STS teaching strategies. The current problems in today's society were seen as too intense to wait until others produce materials and perfect teaching strategies to follow. But, could we have STS if it were a matter of going through a text and following a set procedure in terms of teacher behaviors? One misses the point of STS if one feels text materials are a must--or if one wants precise descriptions of teaching strategies. An STS textbook lends itself to lectures, questions and answers, the same situation as we have with traditional science. Nothing is to be gained by outlining new materials for student mastery. Nothing is to be gained if teachers teach the same way and use the same models for evaluating their students.

Some teachers agree that STS philosophy is good, that the rationale is superior. However, they do not feel that they can proceed unless there are new textbooks or standard examinations. They report their readiness to move to STS science when these conditions are met.

Iowa is not a state where STS has been mandated. And yet it is a state where significant efforts are underway. In 1985 NSTA received a lage NSF grant to initiate a Chautauqua-type short course program for K-12 science teachers. The effort in Iowa focused upon STS for grades 4-9, the grades identified in the state where significant changes were needed. E. Joe Piel was contracted as the primary instructor for the Chautauqua effort.

Basically the plan is to identify 30 teachers interested in developing some new materials to use with some of their own students. Two days are identified (a Friday and Saturday) for learning about STS, some successful examples, teaching strategies, patterns of evaluation. The teachers are then asked to return to their schools and to choose some STS issue for developing a learning module, to test it, and to bring copies of the materials and the assessment of its effectiveness to a second two-day short course some months later. This second part of the short course is a series of reports of the STS experiences, a sharing of successes, frustrations, and future plans. Instructors provide further ideas, analysis, and encouragement.

Now more than 60 teachers have experienced an NSTA Chautauqua Short Course. After the first one the Iowa Utility Association asked to sponsor additional ones where energy would be the recommended STS issue/organizer. An additional 70 teachers have now experienced such industry-sponsored Chautauqua Short Courses. Plans are already set for four new ones for the 1986-87 year which will involve at least 160 new teachers. This summer two leadership conferences are planned for 30 teachers who will become a part of the staff team for the new efforts.

The Iowa STS Chautauqua Short Courses provide a way of starting STS. There is no mandate; there are no textbooks, no added funds. However, there is a commitment to try something new, to work with other teachers, to involve school administrators, to utilize experts that exist in every community. There is a commitment to define a problem that exists in a given community--or a bigger one in the state or nation--about which there is interest in taking some action.

A primary source of ideas for content is the newspaper. The issues of our time are related to science and technology. Other good sources are science periodicals, especially those for the general public. Science 86, Discover, Omni, and others are full of articles of interest--ones usually dealing directly with issues. To use such sources requires some faith that additional information can be found, that students can help locate information, that they can be detectives.

Two years ago Science 84 included the 20 discoveries that most affect us today. The list indicates how questions, topics, considerations can ignite excitement, involvement, and interest. That list included the following:

1. Leo Baekeland's conquest of an unyielding, brittle resin led to nylons and Tupperware;
2. Alfred Binet's method of identifying subnormal school children sired the IQ test and its incendiary implication that intelligence is inherited;
3. In 1905 Einstein formulated relativity, helped to create quantum theory, and clinched the reality of the atom;
4. Everyone who has ever had a transfusion or a transplant owes a debt to Karl Landsteiner's discovery;
5. Karl Pearson's chi-square test measured the fit between theory and reality; ushering in a new sort of decision-making;
6. Lee de Forest's curious variation of the light bulb--the vacuum--opened the airwaves to radio, TV, and telephones;
7. George Shull's experiments with inbreeding and crossbreeding corn make it possible to feed a good portion of the world;
8. Modern aviation got its lift from vacuum clearners and vortices;
9. The transformation of the profession of medicine from an art into a powerfully effective applied science has changed every life;
10. Sixty years ago, only Raymond Dart could show that Africa had brought forth the first human species;
11. Fission has given us a new kind of power and a new kind of war;
12. From the universe's expansion; Edwin Hubble deduced the Big Bang;

13. The miracle of DDT was short-lived, but it helped launch the environmental movement;
14. A Russian immigrant pushed television out of the Rube Goldberg era;
15. Russell Marker's extraction of sex hormones from Mexican yams was only the beginning;
16. First developed in England to break Nazi codes, computers now prescribe cancer chemotherapy and prospect for oil;
17. The discovery of chlorpromazine and lithium emptied mental hospitals and changed our understanding of mental illness;
18. Bell Laboratories wanted something completely new from its semiconductor team. So they invented the transistor;
19. Watson and Crick's double helix launched more than a new science;
20. The invention of the laser excited fantasies of death rays but most of its uses are down-to-earth.

It is difficult to conceive of an issue today that is not related to science and technology. To deal with issues is a means of affecting the future. This idea of controlling our fates--that our actions can affect the future--is an important one that should be central to STS teaching.

Rilke advised the young poet in a way that is also good advice for the STS teacher. Rilke said, "Learn to love the questions themselves, then live into the answers!" The questions (the issues) are important/central for STS programs. These questions/issues must be current and they should be locally relevant. As such they cannot be present via a typical textbook. Every teacher need not plan whole courses--even whole semesters--around STS. And yet every teacher in the Iowa Chautauqua program that has tried an STS module plans to increase the numbers and the time spent on STS for the next year. The students and the teachers have learned to love the questions; and they are living into the answers in every school and every community where there is an STS effort underway.

ROBERT E. YAGER *is Professor of Science Education at the University of Iowa, Iowa City, IA 52242. He is Past President of the National Science Teachers Association and established its Search for Excellence in Science Education Program. He serves on the National Advisory Committee of the Science through Science, Technology and Society Project.*

Bull. Sci. Tech. Soc., Vol. 6, pp. 282-286, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

SCIENCE, TECHNOLOGY, AND SOCIETY EDUCATION: METHODS AND MATERIALS

Irma S. Jarcho

The time seems to be fast approaching when most teachers accept the importance and, indeed, the need for including the teaching of science, technology, and society (STS) issues in the science curriculum.

The reasons for this are obvious. Immense changes have occurred in our society in the last few decades, changes which have been the result of advances in science and technology. Some of the changes have been good, some bad, some pose known risks, some entail risks only dimly perceived. Decisions must be made as to whether or not to accept these benefits and these risks. We cannot leave these decisions to a small coterie of experts. Instead, we must empower the average citizen, providing him or her with a level of acquaintance with STS issues sufficient to reach reasoned judgments. "Technological literacy" is a must for an informed citizenry in a free society.

How are average citizens to achieve technological literacy? If they have reached adulthood before they recognize the need for this information, they must rely on books, newspapers, magazines, and radio and television science programs to acquaint themselves with the major STS issues of the day. It is much simpler and much more effective instead to start this educational process in the pre-college years. The younger they are when they start, the better. It is therefore the task of the elementary and high school teacher and, logically, of the science teacher in particular, to initiate this process of indoctrination for effective citizenship.

The average teacher, however, is unfamiliar with STS issues and before embarking on this new venture wants to know the answer to two important questions:

1. How do I teach the STS issues?
2. Where do I find information on the topics I have chosen to include in my curriculum?

In answer to the first question of how does one incorporate teaching about STS in a science curriculum--there is a variety of approaches and it is up to the teacher to choose the one best suited to the needs of the students or the demands of the system.*

---

*For a more detailed discussion of curricular approaches, the reader is referred to: Jarcho, I.S.: "Curricular Approaches To Teaching STS: A Report on Units, Modules, and Courses," in Science, Technology, Society: 1985 Yearbook of the National Science Teachers Association, National Science Teachers Association, Washington, DC, 1985.

The first approach is the short module--a method developed by Richard Brinckerhoff and Arthur Compton.[1] In their schema the teacher is provided with a series of short, thought-provoking statements intended to arouse class discussion during a regular science period. The teacher is advised to introduce these vignettes shortly before the end of the class period. An example of these "infusion tips," as Brinckerhoff calls them, follows: "A loaf of bread requires far more energy to produce than you gain by eating it. Identify some of the energy inputs." This approach is easy to use, readily available, and provides a minimum of interference with the regular curriculum.

A second approach to teaching about STS is provided by self-contained modules or units, which may last for a few days or a few weeks and which are intercalated into appropriate sections of the curriculum. Sometimes a series of these is put together; then they constitute a semester course or even a full year course. Numerous examples of this STS approach exist. To name but a few, one can choose the series entitled Unified Science Curriculum for High School Students,[2] developd by the Wassau School District in Wausau, Wisconsin. Another is the Individualized Science Instructional System,[3] originally developed by Florida State University College of Education but now available commercially. A third is the Biological Sciences Curriculum Study[4] series entitled Innovations: The Social Consequences of Science and Technology. This series is also available commercially.

Mention has been made of the fact that these modules can be strung together into a semester or full year course. A more formal method of incorporationg STS into the curriculum is to design a semester or year's course dealing entirely with the impact of science on society; dozens of such courses exist. John E. Penick describes some of these in an article in the 1985 NSTA Yearbook.[5] Some courses focus principally on biology, others on energy, or on nuclear sciences, or on other disciplines. The list of courses available all over the country is impressive.

Some schools prefer to attempt a continuing series of modules on topics--modules which bridge several grades. Such an approach is that of the Tulsa, Oklahoma public schools, which developed and implemented what they call the Double E Curriculum--Energy/Environment.[6] There were three texts, one each for elementary, middle and senior high levels. The BSCS units on genetics[7] also favor this broad approach to genetics, with a unit for the elementary grades, one for middle school, and a third for the senior high school.

A final approach to the teaching of STS is the interdisciplinary curriculum. Some label themselves as such because they are team-taught. Such a one is the course Mankind: A Biological/Social View,[8] developd at the Clarkstown South High School in West Nyack, NY. It must be borne in mind, however, that, in their essence, all STS curricula are interdisciplinary, encompassing, as they do, both the scientific concepts themselves and the effect on society of the applications of these principles.

We have thus answered the first question which might trouble a teacher embarking for the first time on the teaching of STS issues. There are, as indicated, a number of possible approaches and it is primarily a question of choosing which approach and which length of module best satisfies the requirements of the course, the teacher, and the students.

Many teachers may still hesitate to embark on teaching about STS because they are not sure of where, or how, they can find the in-depth information they feel they will need. Let them be reassured that a great deal of help is available.

The most direct and, usually the most rewarding, is to enlist the help of networks established for the sole purpose of disseminating information about STS topics. One of these networks is already familiar to readers--the S-STS Project[9] of The Pennsylvania State University. The Project organized and conducted the stimulating Technological Literacy

Conference whose proceedings are embodied in this book. The S-STS Project publishes an excellent newsletter called the S-STS Reporter. Alternate issues of this Reporter contain reviews and assessments of STS modules. Information provided includes subject, grade level, availability, and an evaluation of the scope and content of the module.

Another network is the Teachers' Clearinghouse for Science and Society Education located in New York City. The Clearinghouse publishes a thrice-yearly Newsletter[10] and an annual single-topic supplement. The regular issues report on STS meetings attended by the three teachers who founded the organization. In addition, the Newsletter describes STS curricula developed both in the United States and abroad, as well as reviews of resources available for the teaching of STS. These include curricula, books, films, lectures and lecturers, and a great variety of other data useful to the questing teacher. The special supplements to date have covered such topics as teaching about nuclear war, population education, and water supply and water pollution. The Clearinghouse also provides advice and guidance to teachers interested in developing their own STS curriculum.

A number of networks are devoted specifically to energy issues, among them the Connecticut Energy Council for Teachers with a Newsletter called Connect.[11]

Several networks have been established that foster global awareness in education, among them The Global Tomorrow Coalition, which publishes a Newsletter called Interaction[12] and The Global Perspectives in Education. The name of their Newsletter has recently been changed to Access.[13]

The American Physical Society has established a Forum on Physics and Society which publishes a Newsletter called Physics and Society.[14] The Environmental Action Coalition has a Newsletter called Cycle[15] and the American Nuclear Society publishes a Newsletter for teachers interested in the nuclear sciences--Re-actions.[16]

As to specific STS issues which could be added to the curriculum, excellent information is readily available at low or no cost. Examples of topics and available information follow.

If you want to teach about population, the Population Reference Bureau[17] in Washington, DC, for a very small memberhsip fee, offers teachers study guides, teaching units, and an endless series of charts, graphs, and other pertinent data both on the United States and world population. Among the teaching guides available are, "The Cost and Value of American Children," as well as the more recent, "Food and Population." The latter is particularly pertinent considering the famine in Ethiopia and other parts of Africa.

If you want to teach about genetic engineering, biotechnology, and related fields there is abundant information. Although now a few years old, the excellent report on genetic engineering, Splicing Life,[18] put out by the President's Commission for the Study of Ethical Problems in Medicine and Biomedical and Behavioral Research, is highly recommended as is its companion report on Genetic Screening and Counseling.[18] By themselves, these two volumes could almost constitute a course on the ethical implications of genetic engineering. Several companies offer free booklets on genetic engineering topics. Among them are the Monsanto Company[20] which offers a booklet on genetic engineering and the loan of an accompanying film, and the Industrial Biotechnology Association[19] which has prepared and distributes an excellent series of booklets on biotechnology and related topics.

A teacher could start with what is, to many, the quintessential STS issue--acid rain. The study of this topic involves not only biology, physics, chemistry, and earth science, but also geography, economics, and national and international politics. Curricula for all grades are available for teaching about acid rain. Information about these curricula and other information about the topic are easily availiable from the Acid Rain Foundation.[21]

The Drug Enforcement Administration[22] of the Federal Government, the National Center for Alcohol Abuse[23] and many other organizations provide material on the study of drug abuse. Of particular interest to students are two activist organizations which have recently entered this field, MADD[24]--Mothers Against Drunk Driving--and SADD[25]--Students Against Drunk Driving. Their lobbying is credited with having speeded the passage of laws, which raised the drinking age to 21 in many states.

The list of STS topics is seemingly endless, the supply of information is equally inexhaustible. Perhaps this paper will help to publicize this fact so that teachers can feel emboldened to incorporate STS topics into their reading.

It is not difficult. It can be done and it should be done, so that the aims of the Technological Literacy Conference--the creation of a technologically literate citizenry--can be achieved.

Directory of Curricula and Organizations Mentioned in Text

1. Infusion Tips: Richard F. Brinckerhoff and Arthur Compton, Philips Exeter Academy, Exeter, NH 03833.
2. Unified Science Curriculum for High School Students: John Harkness, Science Specialist, Wausau School District, 1200 West Wausau Ave., Wausau, WI. (Now available commecially as Modular-Science/Technology/Society.)
3. Individualized Science Instruction System (ISIS): Ginn & Co., P.O. Box 2649, 1250 Fairwood Ave., Columbus, OH 43216.
4. Innovations, The Social Consequences of Science and Technology, Kendall/Hunt Publishing Company, 2460 Kerper Boulevard, P.O. Box 539, Dubuque, IA 52601.
5. A Brief Look at Some Outstanding Science, Technology, and Society Programs, John E. Penick, NSTA Yearbook 1986, Washington, DC 20009.
6. Double E: Energy/Environment Curriculum: John E. Roller, Science Supervisor, Tulsa Public Schools, 3027 South New Haven Ave., Tulsa, OK 74114.
7. BSCS Educational Programs in Human and Medical Genetics, Biological Science Curriculum Study, The Colorado College, Colorado Springs, CO 80903.
8. Mankind: A Biological/Social View: Arthur Lebofsky, Clarkstown South High School, Demarest Mill Road, West Nyack, NY 10994.
9. Reporter: Newsletter of S-STS Project, The Pennsylvania State University, 128 Willard Building, University Park, PA 16802.
10. Newsletter: Teachers Clearinghouse for Science and Society Education, 210 East 77th Street, New York, NY 10021.
11. Connect, Newsletter of the Connecticut Energy Council for Teachers, 1800 Asylum Avenue, West Hartford, CT 06117.
12. Interaction Newsletter of the Global Tomorrow Coalition, Suite 1003, Washington, DC.
13. Access Global Perspectives in Education, 218 East 18th Street, Box 10, N.Y.C., NY.
14. Physics and Society Forum in Physics and Society, American Physical Society, 335 East 45th Street, New York, NY 10017.
15. Cycle Environmental Action Coalition, 625 Broadway, New York, NY 10012.
16. ReActions American Nuclear Society, Darlen C. Schmidt, 555 North Kensington Ave., La Grange Park, IL 60525.
17. Population Reference Bureau, 2213 M. St. NW, Washington, DC 20037.
18. Splicing Life: Screening and Counseling for Genetic Conditions, President's Commission for the Study of Ethical Problems in Medicine and Biomedical and Behavioral Research, Government Printing Office, DC 20402.
19. What is Biotechnology? Industrial Biotechnology Association, 2115 East Jefferson Street, Rockville, MD 20852.
20. Genetic Engineering, A Natural Science, Monsanto Company, 800 North Lindberg Boulevard, St. Louis, MO 63167.

21. Acid Rain Foundation, 1630 Blackhawk Hills, St. Paul, MN.
22. Drug Enforcement Administration, U.S. Department of Justice, Washington, DC 20537.
23. National Institute on Alcohol Abuse and Alcoholism, U.S. Department of Health and Human Services, 5600 Fisher's Lane, Rockville, MD 20857.
24. Mothers Against Drunk Drivers (MADD), 660 Airport Freeway, Suite 310, Hurst, TX 76053.
25. Students Against Drunk Drivers (SADD), c/o Robert Anastas, 66 Diane Drive, Marlborough, MA 01752.

IRMA S. JARCHO is Chairperson of the Science Department of the New Lincoln School, 210 E. 77th St., New York, NY 10021. She is co-founder of the Teachers Clearinghouse for Science & Society Education, which is devoted to providing precollege teachers with information on STS, and serves on the National Advisory Committee of the Science through Science, Technology and Society Project.

Bull. Sci. Tech. Soc., Vol. 6, pp. 287-290, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

USING TELEVISION TO BRING SCIENCE, TECHNOLOGY AND SOCIETY INTO SECONDARY SCHOOLS

Minaruth Galey

Nine major studies of education were published in 1984, each referring to the need to prepare our children to be effective citizens in a technological society. Recognition of this need is the basis of a major project now being developed, titled You, Me and Technology (YMT).

Even though we live in one of the most advanced technological societies in the world, a survey in 1978 found no curriculum or course to prepare secondary school students to be successful citizens in this technological society. The 1983 Report of the Carnegie Foundation confirmed that finding.

YMT is a curriculum project. Its subject matter is new for the secondary schools of this country--science, technology and society (STS). This field of study does include a few principles of science and a few of technology, but it is primarily the study of the mutual interactions among science and technology and societies.

STS is easily recognized as providing insight into almost all areas of human endeavor, because technology has impact on almost all of our lives. STS is truly a multidiplinary subject area with applications for all subject areas in secondary schools. However, You, Me and Technology is directed to the teaching of STS rather than using it to teach another discipline. YMT is teaching the subject matter of STS, not teaching science through STS or social studies or ethics through STS.

Development of the YMT Curriculum

The goals of YMT are identified as:

- To develop technological literacy, that is, an awareness of the methods and general principles of modern technology.
- To gain an understanding of the relationships and interactions of:
    - technology and societies.
    - technology and individuals.

- To develop an understanding that technology, in itself, is neither good nor bad.

The content of the curriculum provides a broad overview of the field of STS to serve as an introduction to the field. Although the curriculum design was very well done, there was no apparent interest in an entire course in STS being taught in the public schools. There were no teachers prepared to teach a course. Nor were there any support people or instructional materials for such a course. That situation is changing, but it is likely that for awhile, the greatest use of STS will probably be infusion into classes of science, social studies, career education, technology education and English/communications.

The Roles of Instructional Television

Television offered some unique advantages for implementing the YMT curriculum. Television equipment is widely available in the schools. More importantly, the teachers are familiar with its use in instruction, that is, the need for introductory and follow-up activities for the television lesson to provide a total learning experience.

Role 1. Preparation of Teachers

When television provides the presentation of content, experienced teachers can use the curriculum, or some part it, without special or extensive preparation in the field of STS. Teachers are already experts in one subject matter area. As they learn with their students from the programs and from their professional readings, they will readily gain the knowledge needed to apply at least some aspects of STS in courses of their own specialty area.

Role 2. Visualization of STS Concepts

The capabilities of television to command attention and to place every student in the front seat for demonstrations are powerful instructional tools. Many of the concepts of STS are complex and abstract. By careful selection of examples, the television camera enables the students to see, both literally and configuratively, the concepts and their impact on our lives.

The programs were specified to be 20 minutes in length to fit the typical 50-minute high school period. Each of the 12 topics of the curriculum is described in one program. To give teachers full flexibility in using the programs, they are complete in themselves and can be viewed in any sequence. For example, one teacher might choose to use only Program 4; and second teacher might use Program 9, 2, and 5, in that order.

The formats of the programs vary to promote their individual use. For instance, some are documentaries, some have a host, and others are dramatizations. But none of them are lectures in the television studio. The programs are lively stories about the exciting topics of STS.

Role 3. Dissemination of the Curriculum

The instructional television programs and the Teachers' Guide actually make up the curriculum. The first five programs are completed and available from AIT for purchase or rental. There are four programs in production now, and the final three programs will be ready for dissemination in January, 1988. The Agency for Instructional Technology (AIT) in Bloomington, Indiana is a non-profit educational organization. AIT's business is the marketing and distribution of instructional television programs and the supplementary print materials for public broadcast and audiovisual (classroom) use throughout the nation. In the past 20 years, AIT has built an excellent reputation among educators for reliability and quality in the dissemination of instructional programming.

Content of the Curriculum

A curriculum includes subject matter content, goals, and objectives for the students, teaching strategies, instructional materials and readings. The curriculum designers were chosen for their expertise in STS, regardless of any experience, or lack of it, in the public schools. They wrote the goals, objectives and outline for subject matter content of the curriculum.

The 12 topics under which the content was outlined for teaching the 33 principles of STS, which were judged by the designers to be basic to understanding the field, are listed here in the recommended order for production of the programs.

Living With Technology - consumerism
Decisions, Decisions, Decisions - information processing
The Technology Spiral - four revolutions in technology
Energy and Societies - alternative sources for energy
Health Technologies - social effects, costs and benefits
Feeding the World - agricultural technologies
Communications: The Expanding World
The Fading Romance: Americans and Wheels
China, Japan and The West - transfer of technologies among cultures
Changing Technology and Population Patterns
Exploring Space with Technology
Risk and Safety with Technology

The designers suggested a storyline for developing the topics, but it was the educators who focused the teaching strategies, selected the most meaningful examples and approved the pacing of the programs to fit the needs and interests of the viewing students. They also considered the curriculums of science, social studies, technology education, and English/communications where the programs are very likely to be used for infusion.

Each program does represent a complete presentation of concepts and value considerations, but it is not a complete learning experience in itself. The Teachers' Guide is the mechanism for suggesting classroom activities to complete the learning experience for the objectives chosen by the individual teacher.

For each program in the Teacher's Guide, the guide provides:

An overview of the topic
A listing of the objectives as written by the designers for the subject matter of STS
A summary of the program storyline and content
Two suggestions to introduce the program, including any new objectives the teacher might choose to add
Follow-up activities for the program under the headings: science, social studies, career education and English/communications

The activities were suggested and developed by teachers from four different areas of the nation. Currently, the activities are very simple to do by an experienced classroom teacher, requiring little preparation time or materials.

Instructional materials for use in introducing and/or following up the programs are also included in the Guide. Transparency masters were designed for, and with the assistance of, teachers. Each one could be used for 2-3 programs. The format is simple:

- concept to be taught in the upper left-hand corner
- graphic dominating the central area from which the concept can be introduced and developed
- question indicated in the space across the bottom to lead the discussion to the social effects or human values resulting from the concept.

There is also a list of suggested readings for both the teachers and the students. And a list of additional sources of information relevant to the topics of the programs.

The design materials, the videotaped programs, and the Teachers' Guide provide a complete curriculum for an introduction to the field of STS through the programs, the activities, and the transparency masters to support a curriculum of the teacher's own subject matter expertise. And it becomes apparent to the teachers that they are teaching only one part of the whole field of STS, rather than thinking that any one of the topics is synonymous with STS.

Summary

You, Me and Technology, through its use of instructional television is already bringing a curriculum of science, technology and society into secondary school classrooms. And it is providing a realistic mechanism for use of STS topics in classrooms of science, career education, technology education, social studies, and English/communications. Its full impact will begin when the entire series of programs are available to educators throughout the United States in 1988.

The writer wishes to acknowledge the generous contributiosn of expertise and energy to You, Me and Technology by:

The Designers: E.J. Piel (SUNY at Stony Brook), Leon Trilling (MIT), Richard O'Connor (Dutchess Community College) and Harold Cantor (Mohawk Valley Community College).

The Curriculum Specialists: E.J. Piel, Michael Hartoonian (WI Dept. of Education), Carolyn Graham (NY Dept. of Education), Lonnie Love (GA Dept. of Education), Tom Hughes (VA Dept. of Education), and Peter Haratonik (New School for Social Research in NYC).

MINARUTH GALEY is Professor of Education at the University of Colorado, Denver, CO 80202. She has worked in science research laboratories as well as being a classroom science teacher. Her current research efforts are directed to the applications of technology to education.

Bull. Sci. Tech. Soc., Vol. 6, pp. 291-293, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

A CONCEPTUAL STRUCTURE AND STUDY GUIDES FOR TEACHING ABOUT TECHNOLOGY

David L. McCrory

A Conceptual Structure for Technological Literacy

Technology is an elusive phenomenon, but one of the most cogent definitions is given by Pytlik, Lauda, and Johnson, who define technology as "*a study of the technical means undertaken in all cultures (a universal), which involves the systematic application of organized knowledge (synthesis) and tangibles (tools and material) for the extension of human faculties that are restricted as a result of the evolutionary process.*"[1] DeVore[2] analyzed selected literature in anthropology, history, and sociology and derived three dimensions which serve as a basis for the content matrix illustrated in Figure 1.

One dimension of technology consists of the elements, or constants, which occur in all instances of technology. Todd, McCrory, and Todd[3] identified the elements of technology as: humans, information, energy, tools, processes, and materials. Lenski and Lenski[4] observed that all societies require at least three functional systems in order to survive, namely: communication, production, and distribution (transportation). These three technical systems constitute the contexts of technology, that is, all technological phenomena can be identified as occurring in one or more of these contexts at any time. The third dimension, levels of complexity, refers to the findings of Burke,[5] Mumford,[6] and others who have underscored the significance of technological complexity may actually be a continuum; for purposes of curriculum development this dimension is divided into three categories: handcraft, mechanization, and cybernation.

The content of matrix suggests that "cells" of content can be selected for instruction. For example, a science teacher might choose to focus students' attention on modern methods (cybernation level) used in generating (production context) electricity (energy element). A mathematics teacher could illustrate the calculations (information element) used in computer-controlled guidance systems (cybernation level) involved in space vehicles (transportation context). A technology teacher might choose to focus on the characteristic of fiber-composites (materials element) now used in modern aircraft (transportation context). The matrix also shows the interrelatedness of technology concepts and principles, suggesting that a multi-disciplinary approach to the study of technology could bear much fruit.

Instructional Resources for Technological Literacy

With technology accelerating at a rapid pace, few teachers are able to keep abreast of recent technological advancements and their impacts on individuals and society. New developments in computer-aided manufacturing, robotics, and satellite communication are cases in point. Traditional textbooks are of limited value because they provide few examples of contemporary technology. In short, teachers need more student-oriented, technology-based instructional resouces if they are to develop technologically literate students. Described below are three types of study guides, called "Resources In Technology" (RIT), developed for the Virginia Department of Education. The document formats, and the process used to develop them, are described more fully elsewhere.[7] Some of the RIT materials focus on technical topics such as computer logic devices,

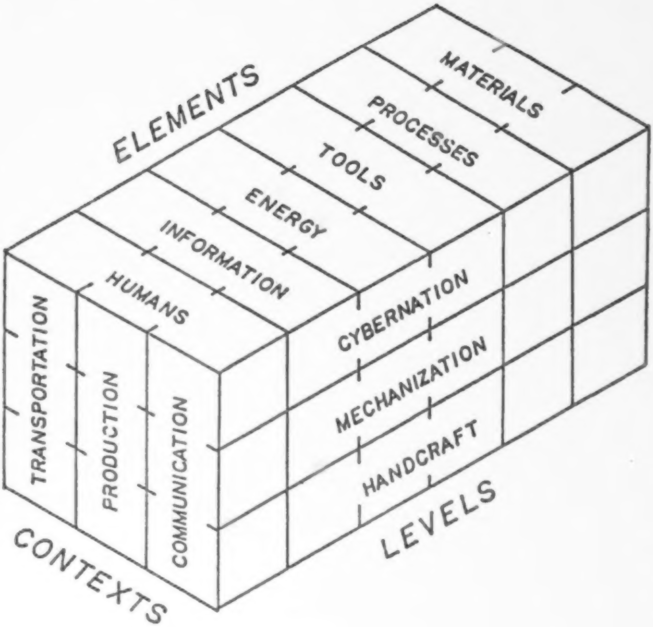

ELEMENTS
MATERIALS
PROCESSES
TOOLS
ENERGY
INFORMATION
HUMANS
TRANSPORTATION
PRODUCTION
COMMUNICATION
CYBERNATION
MECHANIZATION
HANDCRAFT
CONTEXTS
LEVELS

Figure 1. A conceptual model for technology education.

geodesic domes, and electric vehicles while others discuss broader technology-society topics such as energy and the environment and transportation in society. Development of the RIT materials began with the assumption that they should be:

- designed to supplement existing textbooks
- useful for teachers and students
- reproducible by standard copying methods
- written on a junior high school reading level
- free of race or gender bias
- illustrated for reader interest
- socially relevant
- technically accurate
- flexible in use
- short and concise
- technically current.

Thirty-five technology topics were chosen to be divided among three different formats: technology briefs, learning activity units, and monographs.

Technology Briefs were designed as succinct, two-page summaries of major devices, processes, or systems. Normally, only one paragrah per topic was used, with illustrations liberally sprinkled throughout the document. Several references were included for further study.

Learing Activity Packages (LAP) were four pages in length and were designed to be interactive with the learner. Written in a conversational tone, LAPs included stated objectives, topical information, a self-quiz, and suggested learning activities. Illustrations and references were also included.

Monographs, six pages long, provided more in-depth narratives of major themes or topics. Each monograph included illustrations, a list of technical terms, and references for further study. All documents were produced with black line on white 8-1/2" x 11" paper to allow for easy reproduction on office copy machines.

After working with the Resources In Technology project for over two years, the project staff noted several recommendatiosn for those who wish to develop similar materials:

- Do be creative. Experiment with other formats. The ones used for the RIT project may not be appropriate for all situations.
- Don't rely entirely on technical "experts" to write the documents. Content specialists sometimes know so much about a topic they have trouble condensing it into a brief instructional document.
- Do use colleagues in education, business, and industry to help with content input and to provide critical review of the draft copies.
- Don't underestaimte the time required to develop good instructional resource materials. Make sure that adequate time and support are available for research, writing, and field testing.
- Do decide on specific formats and stick with them. Those who are asked to write content will be more likely to produce useful maerial if they are given a pattern to follow.
- Don't hesitate to ask teachers and students to field test and critique draft copies. Feedback from potential users can be very helpful.
- Do select writers who can identify with the needs of teachers and students. If the materials are to be successful, they must be "user friendly."

Note: The 35 RIT study guides described in this article are available in two bound volumes (Resources In Technology and Resources In Technology '85) from Davis Publications, 50 Portland Street, Worcester, MA 01608.

References

1. E. Pytlik, D. Lauda, and D. Johnson, Technology, Change, and Society (Davis, Worcester, MA, 1985).
2. P. DeVore, Technology: An Introduction (Davis, Worcester, MA, 1980).
3. R. Todd, D. McCrory, and K. Todd, Understanding and Using Technology (Davis, Worcester, MA, 1985).
4. G. Lenski and J. Lenski, Human Societies: An Introduction to Macrosociology (McGraw-Hill, New York, 1974).
5. J. Burke and N. Eakin, Technology and Change (Fraser, San Francisco, 1979).
6. L. Mumford, Technics and Human Development (Harcourt, New York, 1967).
7. D. McCrory and G. Maughan, Man Society Technology, 42, 8 (1983).

DAVID L. McCRORY is Professor and Coordinator of the Technology Education Program in the College of Human Resources and Education, West Virginia University, Morgantown, WV 26506-6122, where he teaches graduate courses and directs technology education curriculum research and development projects.

Bull. Sci. Tech. Soc., Vol. 6, pp. 294-297, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

A MIDDLE SCHOOL S-STS TEACHER EDUCATION PROGRAM

Darrel W. Fyffe

Background

The middle grade school years provide the most broadly attended and appropriate educational levels for the introduction of S-STS activities, concepts, and skill development. These are the years during which an increasing percentage of the students reach the level of formal operational thinking. Epstein (1980) has reported that at age 11 there are six percent of the students who are at "Pre-Operational," 49 percent are at "Concrete Onset," 40 percent are at "Concrete Mature," and only 5 percent are at "Formal Onset." By age 15, though, those percentages become 1, 14, 53, and 19, respectively, and the other 13 percent have reached the stage known as "Formal Mature."

The net effect of this change is that during the middle grade school years the cognitive level of the students is changed dramatically toward the higher levels of thought processes. The importance of this finding for curriculum development in the middle grades is great. It would likely be found today that the greatest portion of the middle school instructional materials are based and taught at the formal level of thinking. Some means must be used to bring appropriate levels of curriculum to the middle grade students (Hurd, 1986). One possible solution to this is to use an S-STS approach in which the students become involved in "real-life" (i.e., concrete model) decision making and problem solving situations.

S-STS approaches to teaching science have the advantage of using realistic or actual situations and case studies as sources of information. The student is not requird to have a formal level of cognitive understanding to become aware of the problems involved. It should be noted that developing an understanding of the underlying concerns, issues and concepts may require greater levels of reasoning skill, though.

The introduction of an S-STS approach to the middle grades science curriculum requires the availability of teachers who are familiar with and knowledgeable about the approach, resources, and philosophy. While must of the S-STS movement has been based upon an in-service approach to teacher development, it is presently necessary to conceptualize a program for the preparation of pre-service teachers (Bybee, 1985).

Program Outline

At Bowling Green State University, a TECHNOLOGICAL--SOCIETAL ISSUE APPROACH TO MIDDLE SCHOOL SCIENCE (T-SIAMSS) teacher preparation program is being developed. The intent is to produce a program with an emphasis upon learning and teaching science through utilization of the themes and perspectives of science, technology, and society issues (S-STS). The T-SIAMSS plan is a broad approach to three areas of mutually dependent interests. Those are the:

(1) development of a four-year pre-service program,
(2) implementation of an in-service program, and
(3) preparation of instructional material resources.

The T-SIAMSS project involves the following major aspects of a complete pre-service middle school teacher education degree program:

(1) development and approval of S-STS course syllabi for the teaching specialty content areas of the major in middle school science,
(2) development and approval of course syllabi for the general education S-STS related areas of technological and societal issue content areas, and
(3) development and approval of course syllabi for the professional education program with S-STS specialization in the teaching of middle school students.

The T-SIAMSS project staff will begin to collect, develop, and publish materials which are useful in the education of teachers of S-STS middle school science. These materials are expected to take the form of both teacher pre-service materials and middle school student instructional resource materials. The BGSU T-SIAMSS staff and local educators plan to produce and disseminate a collection of resources to contain the following:

(1) science content and general education course specialty resources which will aid the pre-service teachers in their understanding and application of the science/technology/societal issue interfaces, and
(2) professional education specialty resources which will provide experiences and insights for the pre-service teachers of middle school science through an S-STS approach.

These instructional resources will take the form of:

(1) new materials to present a fresh approach to the teaching of science with technology and societal issues,
(2) collections or bibliographies of already existing materials (i.e., print and non-print aids or activities with explanations) for direct instruction in the program,
(3) local adaptations or expansions of specially produced media (print and non-print), and
(4) appropriate suggestions for the uses of these materials for both the teacher preparation program and the middle school science S-STS curriculum.

It is expected that summer institutes or courses, for approximately 30 practicing teachers per year, will be offered to upgrade the knowledge and skills in the S-STS content areas and teaching methodologies. These courses will be organied to offer experienced teachers the opportunity to study the science, related content, and education fields of the S-STS approach. Most important institutionally, though, will be the value of having a lager cadre of fully prepared middle school teachers of S-STS science in the area with whom our pre-service teacher candidates would be placed for classroom experiences.

Program Rationale

The development of a special program to prepare individuals to teach in the middle schoosl is defensible and implementing an S-STS approach into the science curriculum is important. In 1985 the State of Ohio Department of Education prepared a set of Proposed Standards for Teacher Education and Certification with separate teacher preparation programs and certification for middle school teachers. This middle school certification has not yet been approved, but it is expected that the standards will be modified this year. Several other states have already implemented middle grades certification procedures and standards. This T-SIAMSS project is planned as an organized, institutional attempt to develop the appropriate methods and materials prior to the legislation of statewide standards.

Second, science educators have been recommending the use of an S-STS approach over the past several years. In this project, the concern is with learners at three levels: pre-service teacher education candidates, middle school students of science, and in-service teachers. The successful development of programs for each level will be influenced by our success in preparing for the others. Students at all levels will require a refined knowledge of and skill in using technological and societal issues due to the changes in their environment and society. Individual skill at problem-solving and decision-making is essential in the program.

Third, there is a need to develop materials which pre-service teacher education candidates will find appropriate in developing their understanding of the content of an S-STS enriched curriculum. The need, here, will be to develop courses which enhance assimilation of knowledge in the natural sciences, social sciences, arts and technology. The inter-relatedness of these areas will be stressed through seminars with the science education faculty and field experiences in area middle school classrooms.

Fourth, the development of an S-STS approach for the pre-service teachers will necessitate the involvement of in-service teachers in the development of resources, activities and approaches to be used in the middle school science S-STS classes. At present, the materials available for use in an S-STS approach are diverse and uncoordinaed and often are of little value to the inexperienced science teacher. The in-service applications during this project will assist many practicing teachers as they upgrade their knowledge and skills (Harty and Enochs, 1985).

The T-SIAMSS project is predicated upon the basis that:

1. prospective teachers who experience learning through an S-STS approach will be more accomplished teachers, and
2. curriculum materials of high quality are important if beginning teachers are to utilize the S-STS approach.

Course or Credit Requirements

The State of Ohio Proposed Standards for Teacher Education and Certification suggested the following minimum requirements for the middle school certificate:

"*(A) General education . . . shall include a minimum of thirty semester hours well distributed over the humanities, mathematics, natural science and social sciences.*

(B) Professional education . . . shall include a minimum of thirty semester hours of coursework and clinical and field-based experiences designed for teaching in grades five to nine.

(C) Curriculum content . . . shall include course work of . . . Science--forty-five semester hours." (pp. 29-30)

Of great importance, though, is the mix of courses (Rakow, 1985). For the T-SIAMSS program, the vision is of a series of course requirements which will emphasize the technological and societal issue activity of all three areas.

Program Evaluation

Evaluation of the project will be accomplished through three major types of efforts. Those will involve:

(1) dissemination of the materials produced, regularly, to a selected sample of professional middle school science educators and teacher educators for their use in other trial settings or sample groups,
(2) submission of the materials for publication in professional journals where other, independent professionals will judge their value, and
(3) evaluations of the products and processes by the BGSU faculty and students, State of Ohio Department of Education staff, and the local middle school educators which whom they are involved.

It is hoped that the project to establish the T-SIAMSS program will be underway fully during the coming academic year and continue for three to five years. Progress of the level required for effective implementation of the S-STS approach in the middle school science curriculum is time consuming. However, progress requires taking that first step!

References

Bybee, Rodger W., "The Restoration of Confidence in Science and Technology Education," School Science and Mathematics, 85(2): February 1985, pp. 95-108.

Epstein, H., "Brain Growth and Cognitive Function," in D. Steer (Ed.), The Emerging Adolescent, Characteristics and Educational Implications (Columbus, OH: National Middle School Association), 1980.

Harty, Harold and Larry G. Enochs, "Toward Reshaping the Inservice Education of Science Teachers," School Science and Mathematics, 85(2): February 1985, pp. 125-135.

Hurd, Paul DeHart, "Perspectives for the Reform of Science Education," Phi Delta Kappan, 67(5): January 1986, pp. 353-358.

Rakow, Steven J., "Excellence in School Science," School Science and Mathematics, 85(8): December 1985, pp. 631-634.

DARREL W. FYFFE is Associate Professor of Educational Curriculum and Instruction at Bowling Green State University, Bowling Green, OH 43403-0252.

Bull. Sci. Tech. Soc., Vol. 6, pp. 298-300, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

THE VALUE OF A SCIENCE/TECHNOLOGY/SOCIETY EMPHASIS IN THE ELEMENTARY SCHOOL

Herbert D. Thier

For a wide variety of social, economic, and political reasons there is widespread acceptance that there is a crisis in American education. Funds are being made available to "solve the crisis" and a substantial portion of these funds are being allocated to science education and related fields. Scientists and science educators should focus a significant part of their innovative effort on utilizing science-based societal issues as the basis for instructional development. This focus will lead to excellent instructional materials in science. It will also demonstrate to education and society as a whole the unique importance of science education and science educators bringing about the educational reforms needed in America.

Current, well-founded demands for an increased emphasis on elementary science (N.S.T.A, N.S.B., NSF Policy 1982 and 1983, and NSF Initiative 1986) have brought about a call for change. New developmental efforts directed towards instructional materials and teacher confidence and competency are beginning. I hope that we will use what we have learned from past efforts as the basis for new developmental efforts. Such an orientation leads to an evidence-based, evolutionary approach to change. All too often in education we take a "revolutionary" approach to change, thinking that it is necessary to throw out and/or prove what was wrong with prior efforts. Such an approach neglects what was learned and is incongruous behavior for science educators concerned with fostering thinking and decision making based on evidence.

Let's assume that we will take an evolutionary approach and utilize what we have learned from the developmental efforts of the sixties and seventies as the basis for future efforts. The emphasis needs to be on enhancing opportunities for young learners to have that blend of direct student involvement combined with effective teacher guidance that research is proving so important to the overall cognitive and social development of the individual. We who have the privilege and opportunity of working in elementary science, can make a unique contribution to this goal.

The emphasis needed is one that uses experience-based science as an approach for building increased awareness, knowledge and understanding in young people regarding issues of high concern to them as individuals and society as a whole. By concentrating on the science rather than emotionalism and rhetoric, science/technology/society-oriented materials for the elementary school can help youngsters see the relationship between their study of science and what people need to know to make public policy decisions without appearing biased or representing one special interest group or another. At the same time such materials themselves teach young people basic science and, as important, how to approach problems and issues from a scientific point of view.

Equally important, our experiences in developing and disseminating science/technology/society-related materials indicates clearly that such a focus on societal issues increases dramatically student interest in learning science and teacher interest in teaching it.

The research, development, and implementation efforts of the last 20 years have clearly identified and justified the importance of opportunities for experience in the elementary science program. All current textbook programs now have related experience-based components. Unfortunately, however, many elementary schools still stress reading about science--a hollow substitute--instead of providing the rich intellectual and social experiences that elementary science can be for all youth.

Prior efforts have clearly demonstrated the value of providing actual materials such as batteries, bulbs, and wires in the classroom so that learners can have direct experience with the content and processes of science. Once you work with such actual materials in the science classroom, you quickly realize that how the materials are used is the critical question determining the kind and quality of learning that takes place. Early efforts to simply get materials to the classroom quickly gave way to extensive efforts aimed at understanding what was taking place when such materials were in the classroom. The goal was to take advantage of the opportunities for learning provoked by the experience the students were having with the materials.

We need to rethink our use of "hands-on" materials in the elementary school classroom. For example, the very popular bulbs, batteries, and wires which are part of every "hands-on" science experience can be the basis for a rather rigid, and/or over-simplified teaching experience about an idealization of the concept of a complete circuit.

These same bulks, batteries, and wires can be the basis for a challenging set of investigative experiences that encourage students to make hypothesis, control variables, collect evidence, make inferences and come to conclusions from the evidence collected and, oh yes, also learn the basic principles of a completed circuit. It is not the objects, but how they are used that determines their value in the elementary science program.

For example, one can use the black and white solar trays and thermometers provided in the SCIIS Energy Sources Program (Thier, 1978) to encourage children to design experiments, control and explore variables, and come to conclusions about solar energy and its transfer. The same experience can have the added value of introducing the learners to a major societal issue, namely alternative sources of energy. If that is done the experience becomes much more valuable. To accomplish this the experiments can be followed up with the provision of pictures, video tapes, and other media-based "evidence" that enlarges upon and makes more meaningful the actual experience with the trays. In such a case we are using information obtained from the media to build upon and show the importance of the hands-on experience provided in the classroom. This is one example of what I am calling "heads-on" science, a step beyond experience for the sake of experience. As our concern with technology and society-related issues grows, the use of media as a source of evidence becomes more and more important. Of course how the media is used determines whether it is evidence of just a backdrop for a lecture given to teach the definition of certain terms or the explanation of certain "facts" of science. Learning definitions and facts is important, but facts and definitions learned in the context of "experience" have a different kind of reality for the learner.

Youngsters in our elementary school classrooms now will live most of their adult lives in the twenty-first century. Even the briefest review of what has taken place during this century clearly indicates that the only constant we can promise them is change. Not only their jobs but our whole perception of the world of work and its importance in life may change as more and more tasks are carried out by present-day robots and their "offspring." Medical and other advances may double the average life span again as they did in this century. Starting in 1900 and observing and documenting the change in any societal variable up to today, and then extrapolating future change from that point can lead to positive scenarios that rival imaginative science fiction. On the other hand, if people do not learn to live and deal with people who have different value systems we may blow ourselves off the face of the earth. In such a situation, what can we really help the young to learn that has at least the promise of being valuable to them in the future? My answer: self-confidence and the ability and desire to effectively use evidence as the basis for decision making. Unable as we are to predict the specific situations or issues the individual will face, we need to provide the kind of learning experiences that empower the individual to take on his or her role as a contributing member of our democratic society. Especially in the developmental years of the elementary school, what I am calling "heads-on science," with its emphasis on the use and processing of evidence obtained from a wide variety of sources, has a unique contribution to make to the accomplishment of these kinds of goals. The extent and quality of that contribution will be determined by the nature of the instructional materials designed to encourage such thinking and, especially, our ability to develop a group of instructional leaders who are comfortable using such materials.

References

1. C.A.L.E.E.P. (1986), The California Earthquake Education Project--A Sampler, Lawrence Hall of Science, University of California, Berkeley, CA, 1986.
2. Hawkins, D., "Messing About in Science," Science and Children, 2(5):5-9, 1965.
3. Karplus, Robert and Herbert D. Thier, A New Look at Elementary School Science, Rand McNally and Co., Chicago, 1969.
4. The National Commission on Excellence in Education, A Nation At Risk, p. 25, United States Depatment of Education, Washington, DC, 1983.
5. NSB (1983), "A Revised and Intensified Science and Technology Curriculum, Grades K-12 Urgently Needed for Our Future," Report by the NSB Commission on Precollege Education in Mathematics, Science, and Technology, 1983.
6. NSTA (1982), Science-Technology-Society: Science Education for the 1980's, Position Statement by the National Science Teachers Association, 1982.
7. Richadson, Tom, SCIS, ESS, SAPA: 18 Year Sales History (Preliminary), Unpublished Delta Education, Nashua, H.H., 1985.
8. Shymansky, J., W. Kyle, Jr., and J. Alport, "How Effective Were the Hands-on Science Programs of Yesterday?" Science and Children, 1982.
9. Shymansky, J., W. Kyle, Jr., and J. Alport, "The Effects of New Science Curricula on Student Performance," Journal of Research in Science Teaching #20, pp. 387-404, 1983.
10. Thier, Herbert D., "Science Technology and Society Oriented Curricular Programs at the Lawrence Hall of Science," National Science Teachers Association Yearbook, 1985.
11. Thier, Herbert D., "The Science Curriculum in the Future," National Science Teachers Association Yearbook, 1984.
12. Thier, H.D., R. Karplus, R. Knott, C.A. Lawson, and M. Montgomery, "Energy Source," Units of the Rand McNally Revision of the SCIIS Program (currently published by Delta Education), 1978.

HERBERT D. THIER is Associate Director of the Lawrence Hall of Science, University of California, Berkeley, CA 94320.

Bull. Sci. Tech. Soc., Vol. 6, pp. 301-303, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

THE SOCIAL STUDIES SIDE OF THE S/T/S CONNECTION

James R. Geise

Although science educators have been advocating an STS approach to science education, and many teachers have offered courses, units, or instructional modules devoted to STS issues for many years, educators, in general, are just beginning to look upon STS as a broad national curriculum reform effort. Major organizations have begun to search for definitions, to develop appropriate materials, to think about teacher training, and myriad other issues relevant to such a curriculum innovation. And while science educators have been primarily responsible for the best thinking with regard to STS innovation, social studies educators have indicated increasing interest in this important field.

It may be time, however, for a bit of stock-taking. Both science and social studies education have experienced waves of curriculum innovation in the past. Rather than bemoaning the failures or being satisfied with the accomplishments, perhaps we can learn from the recent history of curriculum innovation to guide us in our current thinking about STS. In this fashion, we may be able to play on the strengths and avoid the pitfalls of past reform efforts.

What are the constraints imposed on any curriculum innovation?

1. Discipline Boundaries

Most secondary teachers perceive themselves in terms of the "discipline" they teach. Thus, teachers of United States history see themselves as historians, teachers of government and civics see themselves as political scientists, and teachers of geography see themselves as geographers. This is a positive view teachers have of their professional selves. The teaching of their "discipline" is probably the better for that self-assessment. Science teachers differ little from their social studies colleagues across the hall. Such self-definition creates professionalism and an atmosphere in which teachers strive to be better within their discipline.

However, discipline boundaries often get in the way of important decisions about what we should teach and how we should teach it. School faculties are divided along discipline boundaries and are sometimes divided within the social studies department as well. The result is that the right hand rarely knows what the left is doing. The social studies teacher knows little about what the science teacher is teaching or when or how science is being taught. When decisions are made about textbook adoption or curriculum revision, etc., teachers from other disciplines are rarely included in the deliberations. Even more chilling, the social studies teachers across grade levels rarely know what is occurring at levels above or below the one at which they teach. Such compartmentalization often precludes significant integration within the social studies and most certainly constrains interdisciplinary approaches to teaching.

2. Testing and Evaluation

One very important reason that innovations such as STS are slow to be adopted is that district and state mandated tests do not include questions relevant to STS issues. Teachers teach to tests and they will do so increasingly as we focus our concerns on educational accountability and student progress. We must remind ourselves that evaluation is important and that teachers' concerns in this regard should be heard loud and clear. We therefore must attend to testing and evaluation of STS if we are to have an impact in many districts and states.

3. Curriculum Scope and Sequence

Innovations such as STS often do not fit into the currently structured scope and sequence of plans of most school districts. This fact may tend to preclude adoption of STS courses with the exception, perhaps, of general science. We would err greatly, however, if this inclusion in general science became the primary focus of STS in districts' scope and sequences.

On the other hand, many of the instructional objectives of STS are consonant with most district's learning goals and outcomes, not the least important of which are the typical citizenship goals virtually every school district mandates. This may prove to be the most important hook on which to hang STS.

4. Teacher Training

Much of the "new social studies" innovation of the 1960s and early 1970s faltered on the shoals of adequate teacher preparation. The materials that were produced were not presented with quality preservice training. While preservice teacher training is no panacea for STS, we must keep in mind that most teachers today have been teaching a long time, and that the experts are estimating that one million social studies teachers wil begin their service in the next five years. We therefore must consider innovations in preservice teacher training consistent with the innovations being considered for the curriculum.

5. Adequacy of Instructional Materials

The range of STS-based instructional materials designed for use in social studies classroom is, at the present time, rather spartan. One of the things learned in the new social studies was that teachers desire self-contained, hands-on instructional materials--materials that require little outside supplementation.

6. The Danger of Being Too Narrow in Defining STS

Social studies educators have much to offer the STS innovation. Social studies teachers typically deal with important public policy issues in their history, government, and current events classes. Many are adept at using alternative teaching strategies and have wide experience in dealing with values questions and decision-making. Furthermore, there are numerous opportunities in the social studies subjects for including STS issues, modules, and perhaps even units of study. For example, teachers of world and U.S. history could include much more by way of the history of scientific thought and much more in terms of the history of technology in the context of their existing courses. Teachers could lead their students to better appreciate the context of scientific investigation, the historic connections between science and technological advances, and the impact of technological innovations in the story of humankind. In this fashion, students who do not have an especially "scientific bent" might come to better appreciate science and the scientific process, and might even want to learn more science. Additionally, government, civics teachers, and their law-related colleagues could teach to current STS public policy issues. Many deal with similar issues already, but all could be encouraged to take an approach that would encourage students to investigate the science aspects of these issues as well as the economic, political, or social aspects.

For the time being, we should not be too rigid in our definition of what STS is or what it is not. We should not be too prescriptive in the beginning, but rather let innovative teachers and curriculum supervisors explore the manifold ways in which STS could be infused, integrated, or otherwise included in the on-going social studies and science curriculum. By saying to social studies teachers that STS can be taught or implemented by doing x, y, and z, we will lose many possible converts and will lose the opportunity to further the scientific knowledge of our future citizens.

One of the obvious deficiencies of most social studies teachers is inadequate knowledge of the science involved in most STS issues. On the other hand, if you can convince them of the importance of STS in the education of their students, these teachers will find many ways to increase the knowledge resource base of their classrooms.

7. The Problem of "One More Reform"

The social studies is subjected to wave after wave of innovations. Currently, there are so many competing "special interests" with regard to social education that the social studies teacher's mind reels when confronting "what to do on Monday." Global education, law-related education, career education, ethnic studies, and all the rest compete for the social studies teacher's attention. It is therefore easy for the social studies teacher to view STS as simply one more thing demanding attention. Thus, marketing of STS must be done in an extremely effective fashion, probably put in the context of helping the social studies teacher do better what they are already doing. Otherwise, many of them will not respond to the call. Things are tough enough already, from their point of view, so STS must be seen as an offer to help them in doing their jobs better.

8. Values-Laden Issues

Finally, we must turn to the problem of the values-laden nature of STS issues. There is no question that STS issues are value-laden. But in the current social environment, how forthright may teachers be in dealing with values and how can we help them do so? In Colorado, for example, some teachers feel constrained tin teaching about the United States Constitution, because many of the issues raised in talking about that document are not value free.

Should we be dismayed by this litany of constraints? The answer to that is unequivocally yes and no. Yes, we should be concerned about the constraints to this significant curriculum innovation. But no, we should not be dismayed. The list of potential problems may serve as a strength, because we know what most of the problem areas are, and we may be able, through concerted effort, to develop strategies for coping with those things that have stifled innovation in the past.

JAMES R. GEISE *is Director of the Social Science Education Consortium, University of Colorado, Boulder, CO 80309.*

Bull. Sci. Tech. Soc., Vol. 6, pp. 304-307, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

ISSUE INVESTIGATION AND ACTION SKILLS: NECESSARY COMPONENTS OF PRECOLLEGE STS EDUCATION

Peter A. Rubba

In what follows, I share the highlights of recent work by Randy Wiesenmayer and myself on a possible empirical base for precollege STS education (Rubba and Wiesenmayer, 1985). We have found the contents of the recent literature in Environmental Education (EE) germane to precollege STS curriculum development and instructional practice approaches from the social responsibility perspective. That is, because EE and precollege STS education have congruent goals--the development in citizens of the ability and desire to take responsible action on social issues--the recent literature in EE on responsible environmental behavior is generalizable to precollege STS Education.

Recent Research on Responsible Environmental Behavior

Factors which contribute to responsible environmental behaviors (actions) have been the topic of intensive study among environmental educators for over a decade. Two recent studies, a regression analysis completed by Sia (1984) and a meta-analysis completed by Hines (1984) have sought to consolidate that body of research by determining the contribution made by particular variables noted in the EE literature toward predicting the environmental behavior of responsible citizens.

Sia (1984) examined the relative contribution made by eight variables to the responsible environmental behavior of members of the Sierra Club and on Elderhostel groups. These predictor variables were individually attributed to responsible environmental behavior in prior investigations. They include: (1) level of environmental sensitivity, (2) perceived knowledge of environmental action strategies (e.g., consumerism, legal action, persuasion, physical intervention, political action), (3) perceived skill in using environmental action strategies, (4) perceived group locus of control, (5) psychological sex-role classification, (6) attitude toward pollution, and (7) attitude toward technology. Each variable was measured with a multi-sectioned instrument developed and validated particularly for that purpose. Environmental behaviors were measured with a second self-report instrument, which also had been validated and shown to be reliable.

The results of Sia's (1984) regression analysis showed perceived skill in using environmental action strategies (accounting for 34.54 percent of the variance), level of environmental sensitivity (accounting for 12.92 percent of the variance), and perceived knowledge of environmental action strategies (accounting for 1.78 percent of the variance) to be the most parsimonious set of variables predicting responsible environmental behavior. The profile Sia developed of a highly environmentally active individual included,

> . . . *(a) versatility of knowledge of and skill in the use of environmental action strageties, (b) versatility in incorporating the five environmental action categories in his/her environmental actions, (c) display of high levels of environmental sensitivity, (d) perception of moderately internal group*

> *locus of control, (e) perception of highly internal group locus of control, (f) moderately negative attitude toward pollution, (g) slightly ambivalent feelings towards technology, and (h) [are] likely to be androgynous in psychological sex role classification* (pp. 184-185).

Also in 1984 Hines conducted an analysis and synthesis of the last ten years of research findings on responsible environmental behavior. This included a comprehensive search of the literature for empirical research and the application of meta-analysis techniques to it in order to determine the relative strengths of the relationships between certain variables identified in the research and responsible environmental behavior. Hines found the variables most strongly associated with responsible environmental behavior to be, (1) a verbal commitment to take environmental action (r = .491), (2) an internal locus of control (r = .379), (3) an environmental efficacy perception (r = .355), (4) attitude toward the environment (r = .347), (5) a personal sense of responsibility for the environment (r = .328), and environmental knowledge (r = .299).

In a model of responsible environmental action, which Hines (1984) proposes from these data, one's intention to act is a primary indicator of the probability that a given environmental behavior will be carried out. For example, one who expresses an intention to conserve energy is more likely to do so than an individual who does not express that intention. However, as Hines points out, the expression of an intention to act does nto ensure one will take the desired behavior. She postulates that a commitment to action is a function of one's (a) knowledge of the environmental issues, (b) capability with environmental issue investigation and action skills, and (c) certain attitude and personality factors. She draws heavily upon research by Ramsey (Ramsey, Hungerford and Tomera, 1981) and Klingler (1980)--discussed later in this paper--to support this supposition.

From the work of Sia (1984) and Hines (1984) the prediction of responsible environmental behavior appears to be attributable to a finite set of variables. These include (a) knowledge of environmental problems, (b) knowledge of the possible modes of action on environmental problems (e.g., consumerism, legal action, persuasion, physical intervention and political action), (c) competence with issue investigation and actions skills, and (d) a number of attitude and personality factors (e.g., environmental sensitivity, locus of control, efficacy perception, personal responsibility, attitudes towards the environment and technology).

The significance of these variables to responsible environmental behavior was forecast four years before the work of Sia and Hines by Hungerford, Peyton and Wilke (1980) in a set of goals for curriculum development in environmental education. Hungerford et al. proposed and content-validated a four-level goal structure for EE which had as it superordinate goal,

> . . . *to aid citizens in becoming environmentally knowledgeable and, above all, skilled and dedicated citizens who are willing to work, individually and collectively, toward achieving and/or maintaining a dynamic equilibrium between quality of life and quality of the environment* (p. 43)

Four subordinate levels of EE are presented under it. Level I, Ecological Foundations knowledge is presented as prerequisite to EE directed at the other three levels. Here, learners develop an understanding of basic ecological concepts such as ecosystems, homeostasis, limiting factors, succession. At Level II, the Conceptual Awareness Level, learners become cognizant of a wide range of environmental issues and the variety of value positions associated with each. Level III EE, Issue Investigation and Evaluation, develops in Learners the knoweldge and skills necessary to investigate environmental issues, propose alternative solutions and evaluate the possible effects. The development of the ability to apply persuasion, consumer, legal, political, or physical environmental actions in the resolution of issues is the aim of Level IV EE, the Environmental Action Skills

Training and Application Level. Providing learners with opportunities to apply investigation and action skills in the resolution of an environmental issue is an integral component of Level III and IV EE, according to the goal structure.

Ramsey (Ramsey, Hungerford and Tomera, 1981) and Klingler (1980) empirically tested the validity of the hierarchy by comparing the effects of EE at Level II with that at Levels III and IV. Junior high school students who received environmental issue investigation and action skills training, and had an opportunity to apply them in the investigation of an environmental issue (Levels III and IV), showed significantly higher levels of overt environmental action than did students who only received environmental issue awareness instruction (Level II), at six-week and three-year intervals following the instruction.

Implications for STS Education

The work of Hungerford et al. (1980), Ramsey et al. (1981), Klingler (1980), Sia (1984) and Hines (1984), strongly suggests that if precollege STS education is to succeed at helping students develop the capabilities and desire to make discriminating decisions on STS issues and to take action on those decisions, then STS educational activities cannot be limited to the awareness level; it is not sufficient for STS curriculum materials and instruction to address learners' attitudes toward science and technology; neither is it adequate for STS educational activities merely to emphasize STS issue identification or account example issue resolution. STS education must guide learners in the development of the capabilities to investigate and take action on STS issues, as they are given practice at applying those capabilities to real STS issues.

The implications of the recent EE literature for STS education are so strong that we (Rubba and Wiesenmayer, 1985) have proposed a four-level goal structure for pre-college STS education which is modelled after that explicated by Hungerford et al. (1980). Adapting the "Goals for Curriculum Development in Environmental Education," developed by Hungerford et al., we propose that STS education which aims to develop issue investigation and action capabilities would have four levels. Level I, the STS Foundation Level, would provide learners with background knowledge in natural and social science concepts, on the nature of science and technology, and on the characteristic interactions among science, technology and society. At Level II, the STS Issue Awareness Level, learners would come to understand how the characteristic interactions among science, technology and society sometimes results in issues whose resolution should involve examining all sides of the issue, as well as the various human beliefs, values and alternate solutions which are associated with each side. Learners also need to become aware that responsible individual and group actions should and can be taken toward resolving STS issues.

Instruction at Level III, the STS Investigation Level, would develop in learners the knowledge and skills which would enable them to investigate STS issues and judge the efficacy of possible solutions. Learners would be given an opportunity to apply these skills in the investigation of STS issues. At Level IV, the STS Action Skill Development Level, instruction would aim to develop in learners the skills involved in taking civil, consumer, legal, persuasive, physical, and political actions on STS issues. Here again, learners would be given opportunities to apply the action skills and evaluate their effectiveness in the resolution of STS issues.

Preliminary evidence on the effectiveness of STS issue investigation and action skill instruction is found in the 10 exemplary precollege STS programs described by Penick and Meinard-Pellers (1984) as part of the NSTA's Focus on Excellence. Each of the exemplary STS programs involves students in the hands-on investigation of STS issues, and in most cases, attempts to resolve the issues through direction action. Notwithstanding, it is critically important for teachers to understand that the ability to resolve a particular STS issue or set of issues is not the end in precollege STS education which emphasizes issue investigation and action. Over a lifetime the STS issues citizens face will change with the evolution of science, technology and society. The true end in precollege STS education is the development of generic issue investigation and action strategies which students can apply to the multitude of new and varied STS issues they will face as citizens.

References

Hines, J. (1984). An analysis and synthesis of research on responsible environmental behavioral. Doctoral dissertation, Southern Illinois University, Carbondale, IL.

Harms, N., and Yager, R. (ed.) (1981). What research says to the science teacher, Volume III, National Science Teachers Association, Washington, DC.

Hungerford, H.R., Peyton, R.B., and Wilke, R.J. (1980). Goals for curriculum development in environmental education. The Journal of Environmental Education, 11 (3), 42-47.

Hurd, P.D. (1985). Perspectives for the reform of science education. Phi Delta Kappa, 67(5), 353-358.

Klingler, G. (1980). The effect of an instructional sequence on the environmental action skills of a sample of Southern Illinois eighth graders. Unpublished master's research report, Southern Illinois University at Carbondale.

National Science Board (1983). Commission on Precollege Education in Mathematics, Science and Technology. Educating Americans for the 21st Century. Washington, DC: NBS.

National Science Teachers Association (1982). Science-technology-society: science education for the 1980's. Washington, DC: NSTA.

Ramsey, J., Hungerford, H.R., and Tomera, A.N. (1981). The effects of environmental action and environmental case study instruction on the overt environment behavior of eighth grade students. The Journal of Environmental Education, 13 (1), 24-29.

Rubba, P.A. and Wiesenmayer, R.L. (1985). A goal structure for precollege STS education: A proposal based upon recent literature in environmental education. Bulletin of STS 5(6), 573-580.

Sia, A. (1984). An investigation of selected predictors of overt responsible environmental behavior. Doctoral dissertation, Southern Illinois University, Carbondale, IL.

PETER A. RUBBA is an Associate Professor of Science Education at The Pennsylvania State University and Director of the Center for Education in Science, Technology and Society (CE-STS), 164 Chambers Building, University Park, PA 16802.

Bull. Sci. Tech. Soc., Vol. 6, pp. 308-310, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

SCIENCE, TECHNOLOGY, AND SOCIETY AND THE EMPOWERMENT OF MINORITY STUDENTS

Dana R. Flint

As our society moves toward the 21st century, the only viable alternative for minority communities is political and economic empowerment,[1] and thus the post-secondary education of minority students must play a key role in enabling minority populations to effectively influence their political and economic destinies. The reason is that the citizen leadership in such communities will come from among those minority youth. But those leaders will need to guide minority communities in a society dominated by technology. As a "field" which focuses on technological literacy for the citizen, Science, Technology, and Society programs will and should be an important ingredient in the post-secondary education of those minority youth who will become leaders in their communities.[2]

This point should be clear once we understand the nature of Science, Technology, and Society (STS) programs, for such programs are concerned with the evaluation of the impact of science and technology on society, and with increasing the capacity of citizens to use such knowledge to shape and influence their environment. As a "field" which starts with a focus on major social issues involving technological impacts, STS does not start with the often highly specialized and narrowly defined problems of particular disciplines. Nevertheless, it does serve to encourage the extension of investigations of particular disciplines into these socially significant areas which, in turn, have a multidisciplinary dimension. This investigation into social issues in which technological impacts are prominent is intended to convert a situation of technology being out of control to one in which citizens become aware of and exert some measure of control over technology for the benefit of people and environments. It is, then, the quintessential knowledge base appropriate to citizen leadership, including leadership in black communities.

The need for technologically literate black citizens is evident when we see that the black worker in the United States has often been the victim rather than the benefactor of technological change, as have the communities in which the worker resides.[3] Most recently, the closing of auto and steel plants and shift to high-technology industries has had a disproportionately negative impact on black industrial workers, whose employment has tended to be concentrated in those older industries.[4] And since blacks hold many jobs which are vulnerable to replacement or deskilling by microelectronics-based automation, black workers may experience a disproportionately adverse impact as more of industry increases their utilization. The introduction of mail-sorting machines, for example, will eliminate the jobs of thousands of black postal workers.[5] Where worker are so affected, black communities will experience the adverse effects of lost income and lost employment.

---

[1] Theodore Cross, The Black Power Imperative (New York, 1984), pp. 837-842. Cross' entire discussion is a thorough defense of the necessity of black economic and political power.

[2] While the focus of this essay is on black communities, similar points could be made regarding other minority groups and women.

[3] Jim Stewart, "STS and Black Studies: Partnership for Progress in the 21st Century" (this volume).

[4] Barry Bluestone and Bennett Harrison, The De-industrialization of America (New York, 1982), p. 54.

[5] Alphonso Pinkney, The Myth of Black Progress (Cambridge, 1984), pp. 92-98. Also, see Cross, pp. 233-256.

Similarly, black communities in large urban areas are often located near polluting industries which may cause illnesses, sometimes years after exposure. While wealthier members of society can move to suburban locations in which the effects of polluting industries are less severe,[6] blacks lacking wealth and having their residential options limited by racism find it more difficult to move away from such heavily polluted environments. Further, black students may suffer the health effects of asbestos in schools or suffer the adverse health effects of lead paint. There is, then, ample evidence to suggest that black workers and black communities are often especially victimized by technological changes, even where these are not racist in intent.

Changes in technology will not always victimize black workers and communities, but the likelihood of technological innovations enhancing the lives of blacks will improve if the leadership in black communities is knowledgeable of their impacts. Such leaders will see the dangers and opportunities of technological innovation, and be able to utilize such knowledge to take action which benefits their communities. Since this is what STS as a "field" aims to do, STS approaches to technology provide at least one very important ingredient in the action-oriented knowledge-base of black leaders and citizens.

STS Education Empowers Black Students

Like other students, black students are concerned with the impact of automation technologies on their personal lives, especially their career prospects. Thus one of their first educational needs is to determine what is going on in the world of work.[7] STS approaches can show students the broad trends in the world of work, including the ways work is transformed by technological change.[8] A study of post-industrial America, for example, may alert students to the obsolescence of certain careers and the new opportunities created by technological change, as well as differential impacts of technology on the careers of minorities. As students develop a discriminating awareness of the effects of technological change on employment, their career choices will be better informed--less likely to end in economic disaster, more likely to contribute to prosperity.

Once they understand the specific ways technological change effects careers, students will be more likely to develop a portfolio of transferable skills which enable them to change jobs and careers with less disruption, where that becomes necessary. But in addition to motivating students to acquire skills which are resilient in the face of technological change, STS Education can provide training in some of those skills. Preferable jobs--such as administrative positions in government and industry--often require skills at integrating a complex range of factors aimed at action or policy. Students in STS programs are required to make assessments of new technologies, and that does involve integration of a complex of technical, economic, environmental, and social factors, all of which are aimed at policy decisions.[9] Students skilled at doing this will strengthen their capacity to compete for those positions. They will increase their personal power.

---

[6] Ian Barbour, Technology, Environment, and Human Values (Westport, 1980), p. 147.
[7] Richard Bolles, Three Boxes of Life (Berkeley, 1981), pp. 205-240.
[8] Discussion with Leonard Waks.
[9] Ian Barbour, pp. 194-205.

While STS education can assist in the empowerment of black students at the personal level, it can similarly empower black communities through educating knolwedgeable leaders of such communities. Students will develop an STS knowledge-base and *habits* of thought and action appropriate to leadership in matters concerning the impacts of technology on communities. By developing of their capacity to make technological assessments, for example, they will understand how to inform themselves of the benefits and dangers of a given technology, and since they will understand the roles of regulatory agencies, courts, and public and private interest groups in the formation of technological policy, they will know where to exert an influence. In being led by such STS-educated individuals, minority communities are more likely to have leaders who are informed about the complexities of questions involved, and who know where and how to take effective action in order to improve the conditions of life and work in minority communities.

Conclusion

STS education at the post-secondary level can empower black students at a personal level and can empower black communities through educating students who will be effective leaders. While it is not the whole of what is meant by the empowerment of black people, STS approaches can be an important *ingredient* in improving the capacity of minority individuals and communities to control their personal and community destinies. If STS can contribute to such empowerment, then it will contribute to the social justice of American society as we move toward the 21st century. Far from being a luxury, STS post-secondary education for minorities in a technology-dominated society is a necessity.

DANA R. FLINT is Director of the Honors Program and the STS Program at Lincoln University, PA 19352.

Bull. Sci. Tech. Soc., Vol. 6, pp. 311-314, 1986. Printed in the USA.
0270-4676/86. STS Press.

TECHNOLOGY LITERACY AND ETHNIC MINORITY STUDENTS

Argelia Velez-Rodriguez

At a time when science and technology play an increasingly important role in everyday life, the average high school student knows little about those subjects, according to a recent National Science Board study.

At a time of widespread recognition that successful competition in a technological society demands increased studies and understanding of mathematics and science beginning at the precollege level, the statistics regarding minority participation doctorates awarded in 1981, Blacks and Hispanics received only 1 percent of those in engineering and the physical sciences and 2 percent in mathematics according to the latest figures from the United States Department of Education. American Indian data are unreliable but there is every indication that their participating rates are as bad, if not worse, than those for Blacks and Hispanics.

There are two major issues facing minorities in their educational development, particularly in the science and technology areas. One is the socio-economic factor and the other issue is the quality of preparation minorities received from grades K-12.

In terms of the socio-economic issue: A 1979 survey found that the higher the educational achievement of the family head and the higher family income, the more likely were high school students to take college preparatory mathematics, physics or chemistry courses. The survey also showed that there is a direct correlation between family income and SAT verbal and SAT mathematics scores for both Black and White students. Further, the average Black family's income is only about 60 percent of the average White family's. There is no indication that the Hispanic and American Indian families are doing any better. This socio-economic distribution results in minorities being highly dependent on financial aid to increase their ability to afford higher education, the situation being critical in quantitative disciplines.

The following table shows the differences in standardized test scores among the various ethnic groups.

Race/Ethnic Group	SAT-V	SAT-M	TOTAL
American Indians	391	425	816
Asian/Pacific Americans	397	513	910
Blacks	332	362	694
Mexican Americans	373	415	788
Mainland Puerto Ricans	361	396	757
Whites	442	483	925

Source: The Admissions Testing Program of the College Board, Profiles, College-Bound Senior, 1981.

With regards to the quality of educational development, most of the minority students receive inadequate preparation either because of overcrowded classrooms, equipment shortages or obsolescence, ill-prepared teachers or some combination of other deterrent factors.

The magnitude and complexity of minority under-representation in science and technology must be addressed through concerted and effective action on both an immediate and a long-term basis.

Studies conducted by researchers indicate that many of the problems associated with under-representation of minorities at the postsecondary level and beyond are attributable to poor academic preparation and lack of exposure to basic science and mathematics at the pre-college level.

Based on personal knoweldge as well as on the years of accumulated program experiences in working with minorities, we have identified a number of factors that appear to have a negative effect on the participation and performance in mathematics, science and technology of ethnic minorities. No one of these factors stands alone but each plays a part. Among the factors which could influence the participation of minorities in science and technology we have identified the following barriers at the various educational levels.

At the pre-college level:

- Limited exposure to scientific and educational materials at home.
- Ill-prepared and often uninterested teachers.
- Low teacher expectations.
- Few or no visible role models in science/mathematics.

At the college level:

- Inability to use scientific or mathematical language.
- Inadequate information on scientific careers.
- Unawareness of the rewards of such careers.
- Inadequate financial support, and consequently, the need for part-time work.

Other barriers found at both the pre-college and college level are:

- Lack of analytical, interpreting and inquiry skills.
- Poor problem-solving skills, study habits and standardized test performance.
- Poor counseling and career guidance.
- Low academic self-confidence.

Many barriers found at the graduate level originate at the pre-college and college levels, such as low academic self-confidence, poor performance on standardized tests, intimidating impressions of the rigors of science study, and poor study habits. In addition, inadequate or no student support services, financial disadvantages, lack of encouragement and sensitivity of many professors and advisors as well as few minority faculty are also preventing factors to the success of minorities in science and technology graduate programs.

There are many ways of helping minorities succeed in mathematics and mathematics-related areas. It is possible to remove the barriers, and to do so in a comparatively short time. Many strategies and programs have demonstrated that there are no inherent barriers to the successful participation of minorities in mathematics and mathematics-related fields. The under-representation of minorities is not the result of a single problem; consequently, there is not one solution.

Based on the data and evidence gathered to date, the following strategies are presented as being effective ways in which teaching approaches and socio-cultural forces can influence science and technology education for different minority groups.

These strategies include:

- Acquisition of new instructional equipment.
- Renovation of existing physical facilities or construction of new ones.
- Special early intervention programs.
- Tutorial sessions.
- Availability of career information.
- Emphasis on career and personal counseling.
- Student and faculty exchange programs.
- Development of innovative instructional methods using computers.
- Undergraduate research and independent study programs.
- Research opportunities and facilities for faculty.
- Part-time and full-time faculty study leaves.
- Improvement of mathematics for non-science majors.
- Strengthening pre-service and in-service training programs for science and mathematics teachers.
- Dissemination of science/technology-oriented information among members of the minority community.
- Continued suppot for successful minority programs already in place.

Conclusions

In summary, we contend that there is a critical need to move with all deliberate speed to confront the challenge. However, we should keep in mind that neither the blame nor the remedy for under-representation lies totally with the educational system. Neither institutions of higher learning, nor the private sector, can solve the problem alone. Increased representation of minorities in advisory bodies and in management positions at the decision-making level of governmental agencies and the various professional scientific organizations would do much to ensure an effective public policy encouraging and supporting greater participation of minorities in science and technology fields.

Increasing minority participation in science and technology must be viewed as an interdependent educational process which requires that all components be implemented simultaneously. The complexity and magnitude of the problems require a comprehensive and coordinated approach involving Federal and State Governments, local education agencies, public libraries, professional groups, institutions of higher education, private sector, parent groups and others. With encouragement, coordination, substantial resource investments and firm commitments, more minorities will not only pursue careers in science and technology but will contribute to maintaining and strengthening the position of our nation as the world's highest technology leader.

References

American Council on Education, Demographics Imperatives: Implications for Educational Policy. Washington, DC, 1983.

Black Issues in Higher Education, Volume 1, No. 5. Reston, VA, 1984.

Higher Education Research Institute, Inc. Final Report of the Commission on Higher Education of Minorities. Los Angeles, CA, 1982.

Minority Institutions Science Improvement Program (MISIP), Barriers Which Impede Minority Participation in Science and Technology. National Science Foundation and U.S. Department of Education, Washington, DC, 1978; 1983 revised.

National Science Board Commission on Pre-college Education in Mathematics, Science and Technology, Educating Americans for the 21st Century. CPCE-NSF-04, 1983.

National Science Board, Science Indicators--The 1985 Report.

National Science Foundation, Science and Engineering Personnel: A National Overview. Washington, DC, NSF 85-302.

The Admissions Testing Program of the College Board, Profiles, College-Bound Seniors. New York, 1981.

Department of Education, Participation of Black Students in Higher Education: A Statistical Profile from 1970-71 to 1980-81, Washington, DC, 1983.

ARGELIA VELEZ-RODRIGUEZ is Program Director for the Minority Institutions Science Improvement Program (MISIP) os the U.S. Departemnt of Education, 400 Maryland Ave., SW, Washington, DC 20202.

Bull. Sci. Tech. Soc., Vol. 6, pp. 315-318, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

STS AND BLACK STUDIES: PARTNERSHIP FOR PROGRESS IN THE 21st CENTURY

James B. Stewart

There is no doubt that scientific and technical fields will play an ever-increasing role in preparing students to meet the challenges of the 21st century. Computer technologies, robotics, and other forms of applied high technology are rapidly proliferating. The response of students to this expected pattern of development has been to flock to the technical and professional fields and to avoid those areas that they perceive as having no bearing on employment opportunities and earnings growth.

This response is, unfortunately, dangerously myopic. The good life that students seek is endangered by the threat of runaway technologies that are applied in ways that threaten human survivability. Progress through technological advance is not insured unless developers and users explicitly pursue that objective. The dangers of technology gone wild are evident, for example, in the history of the development of atomic power.

It is in this context that a synthesis of the frameworks of investigation and content of Black Studies and Science, Technology and Society has a critical role to play in preparing students to be global citizens in the 21st century. Black Studies attempts to use lessons learned from the Black Experience to prepare students to develop technologies that will contribute to widespread human progress rather than perpetuate the exploitation of many for the sake of a few. Both Black Studies and Science, Technology and Society attempt to explore the connections among various activities and institutions in society. This approach facilitates identification of possible unintended consequences of the introduction of new technologies. Such an approach can complement the traditional disciplines which generally ignore inter-connections.

Two of the unique contributions that Black Studies can bring to a Black Studies--Science, Technology and Society partnership are detailed analyses of (a) the history of Blacks in the development of modern science and technology, and (b) the historical pattern of impacts of science and technology on the Black Experience. An early example of the impact of technological development on Blacks is provided by the forces set in motion by the invention of the cotton gin in the 1790s. Up until that point, slavery was a realtively small-scale system. Whitney's invention, however, sparked a dramatic increase in the demand for slaves as the profitability of cotton production surged leading to intensification of Black exploitation.

The institution of slavery did not, however, dull the creative energies of Black Americans. By 1913, Blacks had received in excess of 1,000 patents despite the fact that the vast majority of the Black population could not legally obtain a patent until after the Civil War. Black innovative activity reached a peak between 1870 and 1900, producing many "rationalizing" innovations, directed at improving existing products and processes.

There are a variety of explanations for this pattern. First, during the period of slavery, many Blacks were trained as skilled artisans. With the abolition of slavery, many Blacks were finally able to develop ideas for product and process improvement. Inventive activity was found disproportionately in agricultural and service-related activities, reflecting patterns of exploitations of Black labor and the political status of Blacks.

As was the case for all populations, the efforts of Blacks to exploit new technologies were conditioned by long and short business cycles. In general, the vigorous economic growth in the North and West associated with the closing of the Western Frontier and the emergence of the modern corporation did not trickle down to Blacks. One Black-owned company, the Chesapeake and Marine Railway and Dry Dock Company organized in 1865, was able to buy a shipyard in 1870. By 1877, however, its profits had started to decline and it went out of business in 1883, the same year that the Civil Rights Act of 1875 was declared unconstitutional.

The fact that Blacks remained second class citizens after emancipation meant that they faced access barriers to capital markets. As a result, Black inventors were often unable to benefit financially from their activities. To illustrate, Lewis Latimer invented the first electrical lamp with a carbon filament, an inexpensive production technique for making carbon filaments for lamps and the cotton thread filament which made electric light bulbs practical and inexpensive. However, he was forced to work for Thomas Edison and, as a result, General Electric and Westinghouse reaped the major benefits of Latimer's inventions. Latimer also drew designs for Bell's telephone patent which he was unable to translate into an independent enterprise.

The exception to the pattern of absorption by emerging corporations was Granville Woods who resisted Edison's efforts to hire him and formed the independent Woods Electric Company. Woods did, however, sell important patents to American Bell Telephone, Westinghouse, and General Electric between 1885 and 1900. Eventually, Woods' Company succumbed to the pressures of competition. Even efforts at national mobilization to support Black businesses, resulting in the formation of the National Negro Business League in 1900 by Booker T. Washington, could not ameliorate the basic forces producing a disproportionately small Black business sector, nor its excessive concentration in the service and retail sectors.

As a result of the forces described above, Blacks became increasingly dependent on wage labor to provide an economic base. At the same time, technological advances shaping the basic set of opportunities available to Blacks were becoming increasingly controlled by external forces. The displacement of Black skilled workers by European immigrants accelerated between 1890 and 1910 as employers bowed to pressures to select Whites over Blacks. At the same time, the majority of Blacks were forced to remain in the shadow of the plantation. Unable to migrate freely in response to the beckoning call of the expanding industrial economy, Blacks saw the demands for cheap labor satisfied from the pool of 15 million or so immigrants from Europe that entered the United States between 1890 and 1914.

Only after World War I temporarily disrupted European immigration were Blacks able to enter the modern industrial sector in significant numbers. But even while mired in the agricultural economic backwaters, Blacks attempted to harness Science and Technology to create a better world. The work of George Washinton Carver at Tuskegee Institute, founded by Booker T. Washington, is the classic example. Carver developed over 300 products from the peanut, as well as large numbers of products from the sweet potato and the pecan. Even more significantly, he refused to use his talents for personal gain and he refused the offers of Henry Ford and Thomas Edison to work in their laboratories.

Unfortunately, in the modern urban industrial sector, the foundation was already laid for the continuing isolation of Blacks from involvement in shaping modern technology and its applications. The new transportation technologies, coupled with the creation of the Federal Housing Administration, set in motion the forces that would spur a pattern of rapid suburbanization. This metropolitan expansion would largely relegate Blacks to the central cities until the early 1970s. Moreover, technological developments in communication media also contributed to the isolation of Blacks from the cultural mainstream despite the heroic efforts of the writers and artists who were part of the Harlem Renaissance to make the "invisible" world of Black Americans visible to the entire society.

While Blacks were able to take advantage of World War II to improve their occupational status, this improvement depended largely on gains in manufacturing industries. This same pattern persisted after the war. But the massive exodus from the South following World War II was driven not only by the technological "pull" of the North, but also by a technological push from the South as the traditional agricultural base was disrupted. The invention of the mechanical cotton picker in the 1950s destroyed the historical pattern by which Black teenagers developed an attachment to the labor market. As a result, the unemployment rate among Black teenagers has crept upward steadily from the 1950s to the present as job losses in the agricultural South have not been offset by gains in the industrial North.

More generally, the Black population became caught up in a game of "tag," chasing an ever-evolving set of employment opportunities shaped by changing technologies. Changes in mass production technologies made inner-city multi-floor plants inefficient and sparked a migration of many manufacturing jobs to suburban locations. Black access to these suburban jobs was restricted, in part, by the layout of mass transportation systems and major transportation arteries. As Black suburbanization began to expand, many firms were opting to relocate to the South, successfully lured through tax concessions, industrial bonds, and favorable right-to-work laws. Even the most recent pattern of a large Black return migration to the South has not solved the employment problem as a result of increasing location of production facilities outside the United States.

More generally the decline of major industries, including steel and automobile manufacturing, partially as a result of increasing international competition, threaten the employment patterns that produced some measure of economic stability for the Black working class following World War II. And Blacks have not been able to significantly improve their employment situation as a result of the growth in the service sector that has led to the revitalization of the cores of many central cities in major metropolitan areas.

This raises the issue of what future scenarios are likely for Black Americans. While a detailed treatment of this issue would require a sophisticated integration of the frameworks of analysis of Black Studies and STS, some interesting trends can be observed.

Between 1960 and 1970, 30% of the employment growth in the American economy occurred in professional and technical jobs. The comparable figure for managerial jobs was 6.0%. Between 1970 and 1980, the professional and technical occupations accounted for only 20.3% of employment growth, while managerial occupations accounted for 22.7% of employment growth.

It is predicted, however, that for the period between 1978 and 1990, while professional and technical occupations are expected to account for 20.3% of employment growth, managerial occupations will only account for 7.7% of that growth. If we look at specific occupations, those growing fastest in relative terms are primarily associated with high technology, including data processing machine mechanics, para-legal service workers, computer system analysts, computer operators, office machine and cash register servicers. Two things that should be noted about this anticipated pattern are (1) most of these occupations do not require a college degree and, (2) these five occupations, although they will be the fastest growing in relative terms, will only account for 2.4% of all employment growth between 1978 and 1990. The occupations expected to produce the greatest number of jobs between 1978 and 1990 are janitorial and maintenance workers, nurses aides and orderlies, sales clerks, cashiers, and waiters and waitresses. Of the expected employment growth between 1978 and 1990, these five occupations, alone, will account for 13.3%.

If history is a guide, Blacks, in particular, ought to be especially concerned about these projections. Historically, as has been noted, Blacks have been precluded from sharing equitably in the benefits of technological change. The foundations for a recurrence of this pattern are present. During the current economic recovery, the number of employed Blacks has actually fallen and the unemployment rate for Blacks, relative to that of whites, has increased significantly. As was the case at the turn of the century, Blacks are in increasing competition for low-skill jobs with immigrants, both legal and illegal. In addition, the rapid influx of married women into the labor force in the mid-1970s has also had some impact on increasing Black unemployment. These developments, coupled with the country's growing conservatism and anticipated cutbacks by the Reagan Administration in social services and in enforcement of civil rights laws, portend an increasingly rocky road for all Blacks, including today's college students.

To avoid this quagmire, the historical record as well as contemporary patterns suggest the need for a new type of specialist and planner. These professionals would place human values ahead of profits and not blindly pursue technological change for its own sake. Such a professional can best be trained through a curriculum that provides an understanding of the social implications of modern science and technology.

Although not labelled as such, W.E.B. Du Bois saw the solution to this problem emerging through educational institutions that successfully integrated the concerns of Black Studies and Science, Technology and Society. To illustrate, he argued that by "*starting with present conditions and using the facts and the knowledge of the present situation of American Negroes, the university expands toward the possession and the conquest of all knowledge. It seeks from a beginning of the history of the Negro in America and in Africa to interpret all history; from a beginning of social development among slaves and freedmen in American and [ethnic groups] and kingdoms in Africa, to interpret and understand the social development of all mankind in all ages. It seeks to reach modern science of matter and life from the surrounding and habits and aptitudes of American Negroes and thus lead up to understanding of life and matter in the universe.*"

Today we have the opportunity to realize Du Bois' vision as we prepare for the 21st century in both predominantly Black and predominantly white institutions. Through an STS--Black Studies partnership, the dilemma made famous by Santanya can be avoided: "*Those who fail to learn the lessons of history are doomed to repeat them.*"

JAMES B. STEWART is Associate Professor of Labor Studies and Director of the Black Studies Program at The Pennsylvania State University, 236 Grange Building, University Park, PA 16802.

Bull. Sci. Tech. Soc., Vol. 6, pp. 319-320, 1986. Printed in the USA.
0270-4676/86 STS Press.

EDUCATION TECHNOLOGY: INNOVATIONS

Frank B. Withrow

> *"We raised the power of reason, the power of manipulating words, above all other faculties. The written word became our god. We forgot that before words there were actions . . . that there have always been things beyond words. We forgot that spoken words preceded the written one. We forgot that written form of our letters came from ideographic pictures . . . that standing behind every letter is an image like an ancient ghost. The image stands for natural movements of the body and other living things."*
>
> Frank Herbert

Images, motion pictures, audio tapes, and computer simulations are all vicarious experiences--that can enrich learning. Words and language remain one of our most efficient tools of the teacher. However, we now have the electronic power that can provide images and sounds of sensory experiences. As with most innovations educational technologies come to the classroom only after they have been developed for other purposes. They come from the entertainment, military, business, industry or home markets. Even books were not considered important building blocks for the foundation of the school curricula. Until this century books were used for recording historical events, laws that governed socieites, and ways to express our religious beliefs. The printing of the Bible was for the purpose of people reading the truth for themselves.

Today business, the military and the entertainment worlds use sophisticated learning technologies. Some of these are being adapted for elementary and secondary education. This does not mean that older technologies will necessarily be replaced by the new technologies. There is no danger of books being replaced in the near future by electronic storage devices. It means that educators will have a greater array of tools to facilitate learning. The key, of course, is that economics and efficiencies will dictate the market for information storage formats. It may be that by the year 2000 storing books on electronic chips will be cheaper than printing books on paper.

One of the most often quoted research studies is that a single picture is worth a thousand words. That Socony Mobil study indicates that a large percent of our information comes through our eyes with lesser percentages assigned to hearing, taste, smell and even motor sensory systems. This much-quoted study is interesting but fatally flawed. Learning is most powerful when it is synergistic and we use all of our powers of observation. It is true that a single picture is sometimes worth a thousand words and it is also true that a single word is somethings worth a thousand pictures. The key is to know when to use what information and data source. Obviously, if I am learning music, audition is the more powerful sensory system and if I am designing buildings, graphic displays and plans may be most useful. For the most part, however, we have used speech language and print to store the vast amount of human knowledge that has developed over history. There is a reason for this, because oral and written language is the basis of our thought and memory processes.

It is important to remember that words are the road maps of the real world. Words are useful memory devices that help us organize our thoughts, knowledge, and skills; but they are not reality. I may describe with poetic prose the way I drive a golf ball, but the proof of my ability is my motor skill in hitting the ball.

Technology now affords us the storage and retrieval systems that will allow us to use print, audio, and visual information in teaching and learning. Videodisc and other laser technologies allow us to store and retrieve as the learner needs it, thousands of bits of information in all formats. The 12-inch videodisc stores 54,000 frames of video, the 8-inch disc 24,000 frames of visual information and the CD-ROM 4.75-inch disc can store 270,000 pages of text, 1800 digitized pictures, 1500 floppy discs, or 45000 hours of voice quality sound. The unique thing about laser systems is that any point of information can be retrieved in fractions of a second. The prices of these devices are such that they will soon be available for use in schools.

Two programs that demonstrate the potential of these technologies are the experimental videodisc from The Voyage of the Mimi developed by Bank Street College and the World of Work developed by Tecnivision. Both of these projects received funds from the U.S. Department of Education. They represent important developmental and research examples of this technology.

The demonstration of the videodiscs is obviously a time when pictures and actual manipulation of the programs are more powerful than a verbal description of them. An unedited duplication of a videotape of these programs can be obtained by sending a blank 1/2-inch VHS tape to:

Dr. Frank B. Withrow
U.S. Department of Education
Office of Research and Education Improvement
400 Maryland Avenue, SW
Washington, DC 20202

FRANK B. WITHROW *is Staff Director for the Office of Research and Education Improvement, U.S. Department of Education, 400 Maryland Ave., SW, Washington, DC 20202.*

Bull. Sci. Tech. Soc., Vol. 6, pp. 321-322, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

THE "VOYAGE OF THE MIMI" PROTOTYPE VIDEODISC

Kathy Wilson

At present, very few educational videodiscs have been developed for children in the elementary and middle school years. Most educational videodiscs have been developed by the military and corporate sectors for use in training adults. One of the major goals of the Interactive Video Project at Bank Street College's Center for Children and Technology has been to study the ways that interactive video technology may play a role in children's learning. Toward this end we have pursued two distinct, yet complementary research activities. The first activity directed by Cynthia Char, was designed to observe children's understanding of the unique features of videodisc technology and the contributions that this technology might make to classroom learning. The second activity, under the direction of Kathy Wilson, involved designing, producing, programming, and researching a prototype videodisc based on Bank Street's first "Voyage of the Mimi" television show.

The "Voyage of the Mimi" is an educational package for elementary and middle school children that provides schools with a television show, computer software, and print materials for science classrooms. For our videodisc we drew on themes and footage from the "Voyage of the Mimi" TV show, which is in part a story about a group of scientists and children who study the ocean and observe whales off the New England coast in an old tuna trawler called the "Mimi."

Our goals were several. We wanted to learn about the technical process of making a videodisc and also about the design process of creating videodisc software that might play a role in children's learning and enjoyment. We were interested in experimenting with formats other than "reaction time" games and tightly structured tutorials, which seem to characterize most of the videodiscs for children made to date.

Our design process initially involved selecting two themes from the TV series as the focus for our videodisc. These are map reading and whale identification. Several of the map-related concepts that are introduced on the videodisc are scale changes, chart symbols, and geographic changes through time represented in maps. We edited approximately one-half hour of actual footage from the TV show and stored it on our videodisc. In the level III (computer-controlled) version of the disc, the mixture of narrative and factual information in this footage is used to introduce, motivate, and explain various collections of information and activities. We added approximately 200 slides of maps of the Gloucester, Massachusetts area where the Mimi is docked, oceanographic chart symbols, and humpback whale flukes to the videodisc. In addition we added a short audio clip of an old whaling song ("Blow Ye Winds in the Morning") to the second soundtrack of the videodisc. Picture and chapter stops were put on the videodisc to allow for level I (non-computer-controlled) usage.

A computer program was written (in Basic and Assembly languages) to let children interact with and control the images stored on the videodisc with a reconfigured numeric keypad. We used a Sony SMC-70 computer and a Sony LDP 1000/A videodisc player. Our goal was to create a videodisc design that would be motivating for children and would foster curiosity and self-guided information seeking. Toward this end, we experimented with a series of predominantly visual menus and icons through which a child can navigate to select activities of interest. Free exploration of the information stored on the disc via cursor movement is encouraged by the visual nature of the menus. No directions specifying the sequence in which to access the various activities, represented by icons, are provided. Most of the normal level I videodisc functions, like step, freeze frame, and play reverse were retained in the level III version, as these were found to be highly appealing to children.

In an effort to see how effective our design was with children, we conducted some very small-scale formative research in which we observed children using the videodisc prototype. We first tested the level I version and then the level III version as we proceeded through the design and programming revision process.

Just briefly, the major findings of our formative research with children are described below:

1. First, they like being in control, which included such things as manipulating images where and when they wanted; being able to reverse video sequences, like the whales breaching or one of the characters slicing a banana, or throwing a piece of bread; and making video images, especially of "real people," like the Captain, do things such as stop or step through motions frame by frame when they wanted.

2. Second, they liked the realism of video images and slides, such as the whale footage, the people, and the maps, particularly, the colorful and pictographic maps.

3. Third, they liked zooming in on map images.

4. Fourth, our visual menu structure appeared to be comprehensive to children. They seemed to understand cursor movement using the arrow keys on the keypad quite easily and they were intrigued by the visual aspects of the menus in a way that seemed to encourage them to explore on their own.

5. Fifth, they liked the keypad and found it relatively easy to learn to use; some even wanted to take the keypad home with them.

6. Sixth, children seem to see this interactive videodisc medium as quite different from anything they had done before. As one boy said, "I've done tons of videogames and none of them are quite like this. This is completely different." This type of comment is perhaps partly due to the fact that for most children observed this was the first time they had seen a videodisc. For these videodisc newcomers the realism of the videodisc images and sound seemed to be very different, especially for those kids who have used computers and are familiar with low resolution computer graphics and sound, which are far less realistic than those on videodiscs.

The exploratory approach of our experimental prototype videodisc seems an important and appropriate approach to try with children. Our attempt to use visual menus and icons seemed to picque the curiosity of kids and added to their self-guided exploration of the videodisc. Other computer-generated features, such as wipes, dissolves, and zooms helped children to better make transitions through the subprograms and from one level of the menu to another on their own as they investigated the disc.

We look forward to continued videodisc design and research efforts at Bank Street that will serve as vehicles for research into design principles for videodiscs for children and into the ways that children understand and use videodiscs for both enjoyment and learning.

KATHY WILSON is Director of the Palenque Project and Media Designer at the Center for Children and Technology, Bank Street College of Education, 610 W. 112th St., New York, NY 10025.

Bull. Sci. Tech. Soc., Vol. 6, pp. 323-325, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

CLASSROOM RESEARCH ON INTERACTIVE VIDEO

Denis Newman

The Interactive Video Project at Bank Street began a program of research and development in the fall of 1984 to explore ways of using videodisc and related technologies in elementary and middle schools. The initial funding came from CBS and Sony. This paper reports on some of the background, activities and findings of the project focusing primarily on its relationship to science education.

Background

Over the last 6 years Bank Street has begun several research and development efforts concerned with technology and interactive media for children's education. For example, the Bank Street Writer is an easy-to-use word processor that is now widely used in schools especially at the elementary level. This initial software program has been followed by several others such as the Filer, the Music Writer and the Story Book all of which are tools for children in that they provide structured support for an activity but expect children to supply the specific goal. Children are able to take an active role in creating something new.

Bank Street has also become active in educational television with the production of the "Voyage of the Mimi" under the direction of Sam Gibbon. This 13-episode series, broadcast on PBS, was supported by the Department of Education. The series tells the story of a group of scientists and their young research assistants who charter a sailboat in order to study the Humpback whales off the coast of New England. The series is unique for several reasons. First, science and math concepts are embedded in a story so that they are placed in the context of real world concerns. For example, at one point they are shipwrecked and the captain is unconscious and suffering from hypothermia. The solution to the problem teaches the viewer a lot about the regulation of body temperature and other aspects of biology and physics. The story and the related documentary segments also show science as an active process rather than a set of facts which is an important lesson building toward the student's understanding of the social context of science.

The "Voyage of the Mimi" is unique also because it is accompanied by a set of classroom materials including software simulations and tools which extend the concepts presented in the series into the classroom. For example, in one episode, the Mimi is dangerously off course because the electronic navigation gear is misreading. The captain has to determine their position using a battery operated radio direction finder. The software simulation, Rescue Mission, takes the same basic problem and allows students to try to solve it in the classroom. Students are thus motivated by the dramatic events in the story and actively engaged in solving the problem themselves.

One of the central goals of the Interactive Video Project was to find ways to combine video images, both motion sequences and still frames, with computer control. Microcomputer software can be written to control the videodisc player and call up single video images or sequences thus, integrating information from the videodisc with information from the software. In this way, we hoped to combine the sense of immediacy and involvement generated by video with the active engagement of working with the computer. We also wanted to know what kinds of computer control would be useful in elementary and middle school classrooms. While we were particularly interested in what is called level 3 computer control, we also studied level 1 control (that is direct control via the hand-held controller of the player itself). We should note that by computer control we mean more than just how a computer can control the videodisc player. We were interested in how the student or teacher can control the video images mediated by the computer--this is a question of designing the human interface.

Research in Classrooms

A series of studies was conducted by Cynthia A. Char and William Tally as part of the project (Char, 1985; Char and Newman, 1985; Char and Tally, 1985; Tally and Char, 1985; Char, Newman and Tally, in press). One study involved a field test of videodisc technology in an eighth grade science class located in a public school in east Harlem. For a period of about two months the class used a videodisc player controlled at times by an Apple II computer and two discs produced by Optical Data Corporation. These discs, Space Shuttle and Apollo contained large archives of pictures and footage taken during those NASA missions. These were used in relation to a unit on physical forces such as gravitation, inertia and so on.

The research design involved working closely with the teacher. The researchers wanted to do everything necessary to assure successful use of the materials. By keeping careful note of the kinds of help the teachers requested and/or needed, it was possible to get a clear idea of the kinds of print and software materials that would need to be developed to support the use of videodiscs in classrooms.

Observations of the classroom use indicated a fairly wide range of uses of the videodiscs in classrooms. The teachers used the videodisc as a visual aid for lectures to the class and as a stimulus for classroom discussion and other non-disc-based demonstration activities. Students also used the discs in groups of two or three, the usual configuration for lab work. In these cases, the students engaged in several programmed and worksheet activities developed by the researchers with the help of the teachers. For example, a little adventure game concerned with orbits was programmed using a simple authoring system, Laserwrite, which was supplied with the discs. Students also used the discs for presentations to the class of what they had learned in their small groups. One format that was not found to be particularly useful in the field test classroom was the standard tutorial format used extensively in industrial and military training applications.

The researchers found that the students and teacher were very impressed by the images used in the classroom activities. Students liked the visual nature of the medium. As one student remarked, "In class we have talk sessions, copy sessions . . . we discuss, we write a lot, and we memorize . . . but you forget, because you don't want to go back and read your notes. With the laser disc you see it, and it leaves an impression, and you want to go back and see it again so you understand it better." The realism of the images was also impressive not only because of the quality of the video but apparently because the disc was an archive of original source material of the actual astronauts working in space. One student observed, "It's exciting because you see footage that's real. You don't have to imagine what it's like to be in space or make believe that you are there."

While the teacher and students found the medium extremely appealing, the researchers found that they had a lot of work to do to support the integration of the medium into the science unit on forces. A substantial amount of time was invested in surveying the disc and searching for images that were relevant to the topics of the class. Time was also spent in designing and programming the lab activities. An important conclusion of the field test research is that "raw" videodiscs take a considerable amount of time and effort to use. Probably the review and programming time is beyond what we can expect ordinary teachers to devote in order to use even the most appealing materials. While the teacher has an essential role as expert in the subject matter and in the topics to be covered, other kinds of supporting materials need to be developed to aid the integration of videodiscs into the classroom.

Authoring systems, such as the one used to create the adventure game and other demonstration materials used in the field test, are not likely to be adequate as a source of support to teachers preparing science lessons. First, they are generally limited to a tutorial format which used multiple choice questions and simple branching structures to deliver instruction on well-defined topics. While the researchers did manage to create an adventure game, the activity was extremely limited in comparison to games programmed in lower level languages. The second difficulty with authoring systems is that they tend to take control away from the user of the videodisc. While the student is given the choice to branch in several directions, once he or she arrives at the new images, there is often no flexibility to back up or go forward or step through the images to get a more detailed look. In that sense, the user has less control over the images when the computer is running a program created by an authoring system than he or she does with simple level 1 control. Finally, while authoring systems may be easier to learn than lower level languages such as Basic, they nevertheless require a substantial investment of time to master.

What appears to be needed for computer control of videodiscs in the classroom are programs which provide a fair amount of structure yet still allow the flexibility to use the full power of the videodisc medium. For example, to accompany archival discs such as Space Shuttle and Apollo, a database providing extensive indexing information would be very useful. A database managemetn system could then flexibly search for images along a number of criteria. Such a program might also make it easy to store files which will call up the images in any order thus creating customized "filmstrips" to accompany lectures or other classroom activities. Where computer languages are used to create simulations or games, the structure of these activities should lend themselves to multiple uses such as individual or group play or even classroom demonstration.

References

Char, C. (1985, October). The potential of videodisc technology for children's learning. Presented at the Sixth Annual Nebraska Videodisc Symposium, Lincoln, Nebraska.

Char, C. and Newman, D. (1986). Design Options for Interactive Videodiscs: A Review and Analysis, research report, Center for Children and Technology, Bank Street College of Education, New York: NY.

Char, C., Newman, D. and Tally, W. (in press). Interactive videodiscs for Children's Learning. In Sheingold and Pea (Eds.), Children and Microcomputers: Theory, Research and Development (working title). Norwood, NJ: Ablex Publishing.

Char, C., and Tally, W. (1985). Using Interactive Videodisc Technology in Schools: Four Classroom Case Studies, research report, Center for Children and Technology, Bank Street College of Education, New York: NY.

Tally, W. and Char, C. (1985). Children's Understanding of the Unique Features of Interactive Videodisc, research report, Center for Children and Technology, Bank Street College of Education, New York: NY.

DENIS NEWMAN is Director of the Earth Lab Project and Research Scientist at the Center for Children and Technology, Bank Street College of Education, 610 W. 112th St., New York, NY 10025.

Bull. Sci. Tech. Soc., Vol. 6, pp. 326-327, 1986. Printed in the USA.
0270-4676/86 STS Press.

NOTES ON *WORLD OF WORK* VIDEODISC

Ann Erdman

The WORLD OF WORK is an instructional/training materials package addressing the impact of high technology on today's jobs. It is centered around two 60-minute television programs that highlight changes in the workplace for those seeking jobs, changing careers, or considering the impact of new technologies on business and industry. Using the material in videodisc format, a person may access a variety of information on the subject with very little initial instruction in the use of the technology. Produced by Tecnivision, Inc. of Falls Church, Virginia, under contract to the U.S. Department of Education, the materials serve as a resource for vocational counselors, trainers, educators, and students.

Included in the WORLD OF WORK training package are three double-sided videodiscs, a supplementary handbook, and a program manual. Two of the discs contain the television programs divided into two 30-minute sides each. Students or others using these programs may access the information randomly, using a keypad and an index to identify desired information, or they may view the programs serially, as appropriate. The programs are available on videotape as well as on videodisc; however, no interactivity is possible with the tape. Subject matter contained in these two programs includes the following:

1. "Is Technology Stealing Your Job" presents an overview of those job fields most affected by technology, namely, computers, communiations, information science, and emerging technologies such as robotics. The program highlights the progress of individuals in a variety of work situations that have requird a transition to new technology. It presents current trends in the application of these technologies and what they mean in terms of skills and work. The program includes segments on:

- National Work Trends
- Computers
- Communications
- Information Science
- Robotics
- Word Processing
- Future Employment Forecast
- New Technology Jobs and Skills
- Managmement Attitudes and Skills
- Training
- Personal Initiatives

2. "Where Will You Work Tomorrow" provides viewers with guidance to training opportunities in vocational/technical schools, colleges, and corporate training programs that will open new doors for jobs and careers in the '80's and '90's. Through a series of interviews, it illustrates how individuals can learn techniques of coping with technology's impact on their jobs and futures. The program includes segments on:

- National Job Trends
- Effects of Technology on Jobs

- Technology/Education Relationship
- Coping with Technology

The third disc is designed for interactive use with a microcomputer and contains the two programs described below. It employs a lightpen to assist the user in progressing through a variety of information on the job market.

3a. "Guide to Tomorrow's Jobs" is a visual database of information about different technologies, job trends, skill requirements and training sources. It uses slides, motion picture (from the video material), text, and graphics to give the viewer information on 65 different jobs. The learner can branch through information that progresses from the general to the specific and covers the following information on each job. Much of the material in the programs is based on the U.S. Department of Labor's Occupational Outlook Handbook.

- Nature of the Work
- Working Conditions
- Employment Opportunities
- Training, Other Qualifications, and Advancement
- Job Outlook
- Earnings
- Related Occupations

3b. "The Hidden Job and How to Find It" provides an eight-step process for finding a job, following techniques proposed by noted job counselor, David Perschau. It covers such topics as coping with layoffs, networking to find a job, selling one's skills, developing a marketing campaign, packaging the product, and getting interviews. Random access techniques are employed in this program to enable the student to browse through information in a manner similar to the Job Database program.

The WORLD OF WORK videodiscs are designed to play on all laser videodisc players. Discs I and II were originally designed as one-hour television specials, but have been repurposed for use with videodisc technology at Levels 1 and 3. Level 1 indicates that the discs may be used with a player and keypad only, while Level 3 means there is interaction between the disc player and a microcomputer. The advantage of Level 3 over Level 1 is that searching is made easier and faster. Disc III utilizes Level 3 technology and was designed specifically for this purpose. At the time of its production, it demonstrated the unique qualities of videodisc technology for delivering a varied set of information to a student/user in a form they could manipulate to suit varied purposes. To use Level 3 technology with this set of materials requires a SONY LDP-1000A videodisc system (with graphics overlay module), a SONY SMC-70 computer, and a lightpen.

All audio material in the program is closed-captioned for the hearing-impaired and may be accessed through decoding equipment. The materials may be purchased or rented from:

- Great Plains National Instructional Television Library
  P.O. Box 80669
  Lincoln, Nebraska 68501
  Phones: 800/228-4630 (Toll Free)
  402/472-2007

The 60-minute video programs are being carried on PBS stations and may be taped off-the-air without copyright infringement for use in education.

ANN ERDMAN is Program Officer in the Technology Application Group, U.S. Department of Education, 400 Maryland Ave, SW, Washington, DC 20202.

Bull. Sci. Tech. Soc., Vol. 6, pp. 328-330, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

HUMANISTS, TECHNOLOGISTS AND THE GAP WITHIN

Sotiris C. Kitsopoulos

Ian Ross, president of AT&T Bell Laboratories, has said: "We have not come very far from the days when C.P. Snow suggested that we were becoming two societies--humanists and technologists--with a greater and greater gap between them." These two cultures mistrust each other and often blame each other for many of the ills that befall our civilization. Scientists and technologists see their work as neutral and blame the politicians and the generals if its fruits are used for evil purposes. Humanists don't understand what a technologist does and suspect that it is evil or polluting the environment or diminishing the quality of life.

I reckon that the gap between these two societies has its origin in a similar gap within each one of us. Take Jung's four psychological functions: thinking and feeling, intuition and sensation as pairs of opposites. The thinking type reacts to situations by first analyzing them using the thinking function of his mind. The feeling type, on the other hand, reacts by first ascertaining whether the situation feels right or wrong, whether it has a pleasant or unpleasant value. The intuitive type just knows without being aware of having perceived. Her opposite, the sensation type reacts to the world by relying on his senses to observe it in great detail. Most people tend to favor naturally one or two functions at the expense of the opposite ones. The opposite function tends to have a more unconscious, primitive and raw character. It can surprise, even overwhelm an individual when it breaks through and takes control. We all know cases of normally cool, rational thinking types who totally lose control when their anger or other feelings--including love--takes over. The rare person who partakes equally of all functions is psychologically well rounded indeed. This union of opposites is often symbolized in art, mythology and dreams by a circular pattern, a mandala.

The thinking type is much more likely to be found among scientists and engineers while the feeling type may well be more inclined to follow the humanities or fine arts. Although in the other dimension--the sensation/intuition axis--the situation is not that clear cut, one is likely to find more sensation types among technologists than among humanists. The technologist often fears ambiguity while the poet makes use of it. The artist is sensitive to moods and seeks to express them while many a scientist tends to mistrust and suppress them.

The psyche is full of opposites, of paradoxes, of shadows. Whatever the conscious attitude, its opposite is lurking under the surface. We tend to project this strange unknown, unknowingly, unto others. They, as individuals or as groups, become "the enemy." Here is how Professor Howard Stein of the University of Oklahoma put it in a 1980 article in the New York Times:

> *"Conventional wisdom argues that if only the enemy would change, we would all be happy and resume friendly business as usual. This however masks the more sinister truth that we need our adversaries not to change. We need them for their belligerence and insolence so that we need not face ourselves."*

The way to bridge the gap within is for the individual to become aware of the opposite within, come to terms with it and incorporate it in his or her consciousness. Only

204

then shall we be able to withhold projections and bridge the gaps between groups, societies and cultures. Easier said than done but not impossible. Think of the artist who has the marvelous gift of capturing the environment through observation and of even the minutest detail while at the same time conveying a message that transcends by far the sum total of these details; a message that cannot be expressed by words but only by the work of art itself. The detailed observation is pure sensation; the indescribable message that cannot be expressed by words but only by the work of art itself. The detailed observation is pure sensation; the indescribable message is pure intuition: the gap has been bridged, the union of opposites has occurred. Or think of how the creative comes about, whether it is a poem, a painting, a technological invention or a new scientific insight. As the creator struggles with what is brewing deep inside her, she feels frustration, pain, becomes moody. When finally the idea comes through, she feels elated, overjoyed, in an expansive mood. Then comes the systematic, rational, painstaking work: polishing, grooming, implementing, analyzing, calculating. Feeling and thinking have been united. Indeed the whole process is not unlike the act of creation par excellence: giving birth.

The last pair of opposites I would like to mention is male and female. Man is endowed by nature with certain psychological qualities which are more typical in women, and vice versa. However, because of upbringing, societal pressures and other reasons, such qualities tend to be suppressed. This creates a psychological gap within as well as between the sexes, not unlike the previous gaps. But here is a gap which we seem to be slowly overcoming. Many men today are discovering in themselves qualities that were the exclusive domain of women only a few decades ago: a more differentiated feeling world; a nurturing, empathic approach not only in the family but even within the corporate structure--without losing their masculinity. By the same token, more women are using their thinking function and making their profession in the sciences and engineering--without losing their femininity.

I mentioned the mandala earlier as a symbol of wholeness. Look at the two mandalas in the picture. The one on the top left is the west window of Washington Cathedral, Washington, D.C. and depicts the first chapter in Genesis. The one at the bottom right is an axial view of genetic material (tenfold, B form DNA) generated by computer graphics. It is not as complete as the first one but almost. What is more important, it is not I who juxtaposed these to hint at the role of metaphor and paradox in expressing and unleashing the imaginative. These mandalas actually appeared on the cover of the December 23, 1983 issue of the magazine Science. This is a very good omen indeed that we may be beginning to learn how to bridge our little, big gaps.

S.C. KITSOPOULOS is an electrical engineer at AT&T Bell Laboratories in Murray Hill, NJ 07974, and a psychotherapist in private practice in New York City. He has written poetry in several languages.

Bull. Sci. Tech. Soc., Vol. 6, pp. 331-336, 1986. Printed in the USA.
0270-4676/86 Copyright (c) 1986 STS Press.

REFLECTIONS ON TECHNOLOGICAL LITERACY

Leonard J. Waks

This volume of the Bulletin focuses on the promotion of technological literacy, a key agenda item of American educational reform. Erich Bloch, Director of the National Science Foundation, and Governor Richard Lamm of Colorado review the major issues. Other authors develop concepts and measures of technological literacy, and survey current contents and goals of programs promoting technological literacy at all educational levels from elementary school through the university.

Most of these papers were initially presented at the First National Technological Literacy Conference, held in Baltimore, Maryland, in February, 1986. The positions and arguments presented here will influence the discussion of technological literacy in the coming years, and deserve careful study and evaluation. Here are some reflections on the main themes of this volume.

1. Concepts and Definitions of "Technological Literacy"

Many of the authors in this volume are concerned with the definition or conceptualization of "technological literacy." This is hardly surprising, as the term has at best an indeterminate meaning at present. Professor Haberer distinguishes between "narrow, instrumental" and "broad, cultural" definitions. George Bugliarello makes a similar distinction, while Professor Beaver also notes the indeterminacy and context-dependence of the term. All three opt for a definition which promotes broad, interpretive and critical thinking about technology and its social impact.

The point is that there are indeed competing **definitions** of technological literacy, reflecting different values and needs, and promoting different knowledge, skills, and attitudes, as well as different forms, processes, and content for education. These differences are to be encouraged, so long as the different values and proposed educational programs can eventually be brought to the surface and critically assessed. One potential pitfall of approaching these issues in terms of technological literacy that a single determinate concept may be demanded, which may generate fruitless debate about what the term "technological literacy" **really** means. The genuine question is not what "technological literacy" means (to serve as an effective slogan the term must be open to various interpretations) but what educational efforts related to technology will help us move toward the kind of world we want to live in? There are obviously substantive disagreements about that, and discussion cannot and should not be prematurely closed by definitional fiat.

The term "technological literacy" is, in my view, best thought of as a slogan. It has little specific content, but it has a definite emotional appeal. "Literacy" is fundamental. Those who lack it are flawed and disabled. That is certainly a bad thing. But what is it they lack? This will depend upon what the person using the term values. A person seeking to promote participatory democracy will consider one sort of person a technological illiterate.. An employer seeking a large reservoir of educated workers will mean something quite different.

The use of slogans makes it posible to unite very disparate groups around common themes. We can all agree that we live in a highly technological environment, that it would be desirable for young people to obtain new knowledge and skills to adapt to this environment. Though various groups may differ about what they want young people to learn, they can at least agree that without some intervention no group will get what it wants. Hence they can all join forces in calling out for "technological literacy" now, hoping to shape the programs generated by the "literacy" war cry to fit their values and needs later on. This makes a loosely coordinated national effort possible.

2. Measurement, Curriculum Objectives and Minimum Competencies

If there is no determinate meaning, no specific empirical content, in the term "technological literacy," then how can we gauge our current attainment, or focus educational efforts, or measure their effectiveness? Professors DeVore, Miller and Smalley bring these issues to the fore. DeVore notes that a measure of technological literacy helps us focus on "the current types and levels of technological literacy extant among our citizens," providing information upon which to build and evaluate curriculum and instruction, and determine "public policy relating to the design, implementation, development of technological literacy." Miller and Smalley provide specific measures.

These efforts are useful because they provide concrete and operational meanings for technological literacy. However, there is little consensus about particular measures, which reflect particular choices, whether those of the test inventors or of participants in a Delphi survey, etc., about what knowledge, skills and attitudes are important and worthy of being promoted. It is one thing to measure how many people think they know how a telephone works, or believe in lucky numbers. And we may have perfectly good reasons for carrying out such measurements. But it is obviously quite another thing to add them together, call the result "techological literacy," and make that a focus of education or policy efforts.

Beyond this, specific measures or operational definitions are not really needed to focus work at the start of major curriculum efforts. Indeed, sometimes premature criterion measures hamper curriculum development (Atkin, 1963). The term "technological literacy" has an heuristic value, capable of stimulating imaginative curricular frameworks among those with appropriate knowledge and experience. Cecily Selby offers one such conception, without providing an operational definition of goal variables. Professors Bauman and Herzog offer another. In implementing such frameworks, relevant measurement questions will inevitably crop up, and specific tools can be developed to handle them, without begging important questions by demanding premature closure about criterion variables or measureable objectives.

A related question is frequently posed: what scientific and technological knowledge and skill should be possessed by all Americans? What is the bare minimum which every American should possess? This question is a starting point for Project 2061 of the AAAS, and is a good heuristic, because it can bring informed people with many interests and points of view around the table to "brainstorm" about future needs. I have been able to preview drafts of two 2061 panel reports, and they are reflective and useful documents. The question of minimum knowledge and skills can be taken too literally, however, and therein lies another pitfall.

The question of minimum competencies asks us to think about the "typical," or even the "typical slow" learner, but there is no such person. It focuses our attention away from all of the concrete facts. What are the people who drop out of school really like? How about those who have the hardest time with logico-linguistic learning? What do we really know about those at the mean on this sort of learning? A standard deviation below the mean? Are many or most of them good at something else? Do some of them manage to learn some mathematics and science? How many, and how much? What can be expected, under reasonably favorable circumstances, of the one-third of all kids lying between the mean and a standard deviation below? How much variability may we expect among them in interest and ability to learn? Ethnographic studies may be a useful starting point in conceptualizing useful goals for such learners, but the question of minimum competencies rarely promotes such studies.

When we speak of participatory democracy, we do not imply that each and every person will play the same role, or even an active role, in the political process. Some people have more interest, more talent, more time, more personal need, than others. What is needed is that a critical mass of individuals in many vocations and at many social and economic levels, can be recruited for the political process, whether acting through voluntary associations such as labor unions or neighborhood groups, political parties, or official political bodies at various levels. A full chorus must be heard, and no voice may be excluded. This cannot be achieved by compulsory programming of a static bare minimum for all, but only by widening responsibility and active participation, and hence increasing the personal felt need for knowledge and skill across the population spectrum.

Professor Layton's conception of science for specific social purposes ties in here. Layton argues that our concern for broad scientific and technological literacy is not (or at least should not be) the desire to promote inert learning of ideas which, while meaningful to the scientific and engineering communities, are irrelevant to citizens in their specific circumstances, with their specific needs. Rather, the public must be functionally literate about the science and technology related to their specific needs and roles, and this may be quite different than anything the scientific and engineering communities have identified as "basic," or have even investigated.

3. Teacher-centered vs. Learner-centered Approaches

Central to technological literacy in my view is what might be called "technology self-concept," the structure of "I statements" each learner believes and asserts. "I can't do math--its too hard." "I like making things by hand and I'm good at it." "I can read and learn what I need to know about any important political question." "I'm a klutz--all thumbs."

I accept Howard Gardner's basic insight that there are "multiple intelligences" (Gardner, 1983). Not everyone is equally good at logico-linguistic learning; this doesn't mean that the less talented in this dimension are unintelligent. Some learners will excel at learning concepts and theories, or at solving difficult mathematical problems, or at thinking up creative solutions to the mega-problems facing the nation. Others will take to science and technology by way of hands-on skill or interactions with the natural world. Other will link to technology through their interests in art or music.

We cannot equalize all kinds of learning for all merely by providing well-designed courses of instruction. There simply are no educational interventions so well designed that they are good for the learner-in-general, because there is no such learner. On the other hand, if we assist young people in finding out what they are really good at, and then provide all the assistance, facilitation, and coaching that they can use, setting them to work at challenging projects largely under their own direction and control, and providing information through lecturettes, readings, and modular self-study materials which relate to these projects, then most of them will perceive science, math, and technology as essential resources. Each, in his or her own way, will be enabled to develop a positive technology self concept. "I did it!" "I learned it!" "I was able to read it and understand it." And they will learn a lot, because it is "relevant" to them.

For those who start off without special talent in science and math, teacher-centered instruction--systematic lectures, demonstrations, training sessions and drills, followed by exams, has special flaws. It puts these "slow" learners (who may be "fast learners" about things which we, in many cases without any reasonable basis, do not value as much as we value logical and linguistic facility) into a frustrating, no-win, one-down encounter which paralyses much of the intelligence which would otherwise be available for learning.

There is great potential to reverse this process in STS education, but much depends on how it is implemented. Professor Yager notes that because STS instruction is organized around issues, there is a change in the role of both teacher and curriculum content. Content does not exist to be mastered, but unfolds as "factors needed for dealing with specific issues." Basic information is not that which is identified in advance, but rather that which empowers the learners in dealing with the issues they have had a hand in selecting and shaping. In their articles, Irma Jarcho and David McCrory identify information resources which may be useful in such contexts. Jim Geise ntoes that social studies teachers have both skills and hands-on experience to contribute to the discussion about how to handle value issues and learner-directed projects. John Brockway adds that learning experiences in natural settings (e.g. hospitals, where technology is attached to real people) help students to "integrate radically different knowledge sets." A teacher in these contexts, says Yager, is a "facilitator, an organizer, a leader, an arbitrator, a guide." For Yager, this issue and project approach is "basic to STS courses."

4. The Political Culture and Learner-Centered Methods

We may think of our **political culture** as our way of recruiting and training individuals for social decision-making, and organizing the decision-making process in both voluntary organizations and political bodies. This culture is largely informal. It is based upon expectations. How much do we expect our neighbors or co-workers to know? Do we expect them to have strong opinions, backed by argument? Do we expect them to play an active role in public life? Is informed discussion about the issues of the day one of the great joys we share? Can effective publics form on the central issues? Or do we discourage the political interests of masses of people, leaving politics to those with special interests and expert knowledge?

An active and open political culture can recruit and train citizens effectively. Once a person feels internally that he or she counts and can make a difference, takes a stand and takes action, each step provides feedback about what else must be known, what skills must be formed. Effective action is "learned by doing." It is always a boot-strapping affair. No compulsory programming of passive individuals can lead to effective action. We can also consider the political culture in schools and colleges. A learning environment generating and supporting projects under learner control, tied to responsible action, will do more to promote engaged citizenship than any course of lecture-discussions on "technology and society." Some examples: getting out a newsletter on S and T issues in the state legislature; measuring levels of a pollutant in a local river; organizing a protest meeting. Professor Rubba summarizes the research support for this proposition; if we want to promote attitudes of issue-investigation and responsible social action, we must involve learners directly and consciously in such activities.

5. The Role of the Liberal Arts

In different ways Professors Haberer, Beaver, Brockway, and Mitcham address the role of the liberal arts in promoting technological literacy. The Sloan Foundation, through its New Liberal Arts Program, has been assisting the development of quantitative and technology-related courses as part of general education in many of the nation's colleges, and the Council of Independent Colleges is also mounting an effort.

What are the goals of the "new liberal arts" programs, and how do they relate to the traditional liberal arts ideal? Professor Brockway states that it took about two years for the goals of the Davidson College "new liberal arts" program to become "refined," but eventually three goals emerged: (1) to present engineering principles as part of the undergraduate liberal arts curriculum, (2) to recognize that technology and quantitative reasoning should play a central role in that curriculum (Brockway's emphasis), and (3) to recognize that "liberal education must include frequent experience with technology and with quantitative methods of solving problems over a wide range of subjects and fields."

The Davidson program as Brockway describes it (without making any claim that it is typical of the "new liberal arts" programs) clearly promotes broad interpretive and critical skills, but that is not evident in these stated goals. That worries me. Professor Steven Goldman at Lehigh, among others, has spoken about the potential of the "technological literacy" movement to become a vehicle for the uncritical inculcation of pro-attitudes about the latest scientific and technical developments. Jacques Ellul (1964) has gone even further, insisting that modern "technique" inevitably reshapes all institutions to serve its requirements. He says that new educational movements must:

> *correspond exactly to the role assigned to education in modern technical society . . . Education is becoming oriented towards the creation of individuals useful only as members of the technical group. The intelligentsia will no longer be a model, a conscience, or an animating intellectual spirit for the group, even in the sense of performing a critical function. They will be the servants of the instruments of technique . . . Education will no longer be an unpredictable and exciting adventure . . . but an exercise in conformity and an apprenticeship to whatever gadgetry is useful in a technical world* (p. 348-349).

It is worth re-reading the Davidson goals against this background. The question remains whether there is any relevant connection between "technological literacy" and the liberal arts ideal. The liberal arts, as Mitcham notes, have traditionally been divided into two groups: the trivium of basic studies in logic, rhetoric, and grammar (= language and literary studies) and a quadrivium of abstract and mathematical studies: arithmetic, geometry, astronomy and music. Mitcham notes that historically (e.g. in Aristotle's Politics) these mathematical studies were associated with technical endeavors such as surveying, pointing to a continuity between the liberal arts tradition and these "new" liberal arts.

The discontinuities are also considerable. The abstract, mathematical and scientific studies of the quadrivium, which entered the educational mainstream by way of the Pythagoreans and Plato, were related to their ideals of the theoretical life. By participating in the abstract, the universal, eternal, and hence **perfect** realms of e.g. astronomy or geometry, the learner was removing his conscious attention, and hence anxious concern, from the particular, ever-changing, and very imperfect world of everyday life, and participating in the realm of the divine. These ideals, as Mitcham notes, were echoed in such medieval Christian educators as St. Augustine. Mitcham calls our attention to Hugh of St. Victor, who proposed to supplement the seven liberal arts with seven mechanical arts--pointing to the conceptual divide between the quadrivium and technology.

Since Bacon and Galileo, Western thinkers have formed a radically different view of the value of scientific studies. Instead of lifting us out of the world, science would teach us to dominate it. By fitting the theoretical and mathematical methods of Greek science with the ideals of these thinkers, modern technologists have transformed every aspect of life and its environment throughout the globe. This has created our contemporary problematic--learning to understand and control technology itself. Today this is very much a part, and maybe the most important part, of what it is to achieve freedom--freedom from the clutches of technology to make autonomous personal decisions and participate in the informed governance of the community, the nation and the planet.

This new problematic indeed requires new arts. Instead of reshaping the quadrivium to promote technological literacy, we may be better off creating a modern counterpart of Hugh of St. Victor's mechanical arts, in the context of the global technological system.

These new technology studies would aim to prepare us for responsible life in a changing and imperfect world, as the old quadrivium sought to enable us to transcend it, and find a reference point for our lives within it, through participation in an unchanging and perfect realm.

Such studies are the core of STS. Many alternative approaches should be tried, but two temptations must be avoided: (1) the reduction of technology studies to a mere instrument of social adjustment, and (2) the development of these studies merely as special academic disciplines, increasingly refined and irrelevant. Instead, they should be integrated in general education, as arts--complexes of skills--for interpreting the problems facing the human community and for addressing them practically and effectively, as an expression of responsible freedom in the technological age.

References

Atkin, J. Myron. "Some Evaluation Problems in a Course Content Improvement Project," Journal of Research on Science Teaching, 1, #2, June 1963, 129-32.
Ellul, Jacques. The Technological Society, New York, Vintage, 1964.
Gardner, Howard. Frames of Mind: A Theory of Multiple Intelligences, New York, Basic Books, 1983.

LEONARD J. WAKS is Professor of STS at The Pennsylvania State University, 128 Willard Building, University Park, PA 16802. He serves as Chairman of the Program Committee for the Technology Literacy Conferences and as Special Issues Editor of The Bulletin of Science, Technology & Society.

NOTES

NOTES

BULLETIN OF SCIENCE, TECHNOLOGY & SOCIETY

Instructions to Authors

EDITORIAL OFFICE: Materials Research Laboratory, University Park, PA 16802 USA.
Editor-in-Chief: Rustum Roy
Managing Editor: Kathleen S. Mourant

INTENDED READERSHIP

The *Bulletin of Science, Technology & Society* is designed to provide a means of communication within as wide a spectrum of the STS community as possible. This includes all faculty and students from many disciplines in the newly emerging groups on university and college campuses which teach integrative STS subject matter; professionals in government, industry and universities, ranging from philosophers and historians of science to social scientists concerned with the effects of science and technology, and scientists and engineers involved with the study and policy-making of their own craft; and the concerned general reader.

SCOPE

The editors welcome the submission of appropriate manuscripts including:

- Educational modules for instruction in STS courses. Appropriate subjects include: the place of science and technology in societies; technology, science and public policy; technology assessment; impact of technology upon human values and religious insights; and the public understanding of technology and science.
- Course outlines, curricula descriptions and reviews of all kinds of educational material (i.e., in various media).
- News items regarding public and scholarly events in the area of STS.
- Short articles of relatively general interest in the STS field.
- Responses to earlier Bulletin articles.

FORMAT

Manuscripts for articles and educational modules should be written in English. *Articles* should be accompanied by a short abstract. Complete address(es) and a short (60 word) biography of the author(s) must be included.

All materials will be formatted in the editorial office with a copy sent to the author for proofreading before publication. [Specially formatted typing sheets, along with instructions, will be provided on request from the editorial office to any author who wishes to prepare his/her own manuscript.]

Manuscripts should be submitted in duplicate (including figures), typed double-spaced. Tables should be included as part of the text and must have headings. Line drawings, preferably in the form of glossy prints should be supplied at least of the size in which they are intended to appear. Halftone pictures should be supplied as glossy prints in the actual size (or slightly larger) in which they are to appear. They should *not* be pasted in. All figures should have legends and the figure number and author's name should be clearly indicated on the reverse side of each illustration.

Materials for news and similar items should be prepared in the same format as for articles, omitting the abstract and biographical material.

REFEREEING

Authors are invited to submit contributions directly to the Associate Editor or Co-Editor of their choice (if they prefer open-reviewing and personal communication of the manuscript) or to the Editorial Office (if they prefer traditional anonymous review). The Associate Editor or Co-Editor may accept, reject or require any changes she or he sees fit. They may also turn the paper over to the Editorial Office, if the author consents, if they do not feel competent to review the paper. Communication of an article by an Editor signifies an acceptable scholarly level, not concurrence in the views expressed.

REFERENCES AND STYLE

A reference section following the text must provide bibliographic data for all works cited or quoted in the text. The style for references are as follows:

Journal:	T.D. Sterling and D.M. Kobayashi, Environ. Res. *13*, 1 (1977).
Book:	P. Brodeur, The Zapping of America – Microwaves. Their Deadly Risk and the Coverup (Norton, New York, 1977), pp. 100-102.
Chapter:	F. Dachille and R. Roy, Reactivity of solids, J.H. de Boer, Ed. (Elsevier, Amsterdam, 1960), p. 502.

COPYRIGHT

All authors must sign the "Transfer of Copyright" agreement, available from the editorial office before the article can be published. Government employees whose submitted work was prepared as part of their employment are exempt from the transfer requirement, but must certify their status as government writers. This transfer enables STS Press to protect the copyright material for the authors, but does not relinquish the authors' proprietary rights or rights to use their work as they please in the future.

Subscribers are automatically granted the right to reprint all original material published in the Journal, with proper acknowledgement as to its source. This new, fast growing method of on-site, on-demand reproduction provides reviewed teaching materials at costs well below traditional textbook expense to subscribers.

REPRINTS AND SINGLE ISSUES

Senior authors will receive a form for ordering reprints and complete single issues in which their article appears. 25 free reprints are provided to senior authors. Orders for additional reprints must be received before printing in order to qualify for lower prepublication rates.

SPECIAL DOUBLE ISSUE ON TECHNOLOGICAL LITERACY

Volume 6, Numbers 2 and 3 1986

INTRODUCTION

RUSTUM ROY 131

MAIN PROBLEMS AND ISSUES

ERICH BLOCH 138
CECILY CANNAN SELBY 146
RICHARD D. LAMM 152
GEORGE BUGLIARELLO 159

TECHNOLOGICAL LITERACY: CONCEPTS AND MEASURES

WILLIAM F. WILLIAMS 163
STEPHEN JAY KLINE 164
LEE SMALLEY 188
JON D. MILLER 195
PAUL W. DeVORE 202
DAVID LAYTON 210

HIGHER EDUCATION

LANGDON WINNER 219
JOSEPH HABERER 222
DONALD deB. BEAVER 229
CARL MITCHAM 235
JOHN P. BROCKWAY 240
JUDITH ADAMS, PAUL DURBIN and RACHELLE HOLLANDER 246
STEPHEN H. CUTCLIFFE 255
CORRINNE CALDWELL 257
JAMES C. WILLIAMS 259
M. GARRETT BAUMAN and ROBERT H. HERZOG 261
NEAL A. NORRIS 268

KINDERGARTEN THROUGH GRADE 12

ROBERT A. YAGER 276
IRMA S. JARCHO 282
MINARUTH GALEY 287
DAVID L. McCRORY 291
DARREL W. FYFFE 294
HERBERT D. THIER 298
JAMES R. GEISE 301
PETER A RUBBA 304

TECHNOLOGY LITERACY AND THE MINORITY LEARNERS

DANA R. FLINT 308
ARGELIA VELEZ-RODRIGUEZ 311
JAMES B. STEWART 315

INNOVATIONS IN EDUCATIONAL TECHNOLOGY

FRANK B. WITHROW 319
KATHY WILSON 321
DENIS NEWMAN 323
ANN ERDMAN 326

MISCELLANEOUS

SOTIRIS C. KITSOPOULOS 328

AFTERWORD

LEONARD J. WAKS 331

BSTS 6(2&3) 131-336 (1986)
INDEXED in Current Contents, Sociological Abstracts, Engineering Index, and Social Science Citation Index